THE INTERNATIONAL PLANT PROPAGATORS' SOCIETY: A DYNAMIC ORGANIZATION THAT SERVES YOU

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The International Plant Propagators' Society is as good as its members *want* it to be. Our Society is *US*—you and me, not *THEM*—some shadowy group of strangers! It has been my very great privilege to attend meetings of several of the Regions that comprise IPPS, Inc., and I come away from each meeting feeling a unique sense of pride that I belong to such an organization!

During the past five annual meetings of the International Board, I have heard increasing concerns expressed by the Directors over various aspects of the policies and rules under which we operate, such as the relationships of the Regions to each other, and the relationship of the Regions to the International body. Finances, publications, forming new Regions, voting rights, Region's rights, are frequently on the agenda for discussion. This is GOOD! An organization worth supporting is an organization that serves the needs of its members and, truly, an organization must change as the needs of its members change.

Most of us know more about our own Region than we do about the Society, Inc. This is as it should be, since one of the unique aspects of our Society is the degree of autonomy each Region has in running its own meetings and affairs. However, the *Society* is under the direction of the International Board of Directors, and it is here that the international aspects of our organization take shape and meaning. As you know, the Board is composed of one Director elected by each Region, plus the International Officers, elected by the Board. The Board is charged with the management and control of the affairs and of the property of the Society, and the expenditures of all funds.

How did it all start, and where are we going?

IN THE BEGINNING . . .

As you read through the proceedings of the various inaugural meetings of the IPPS, several names keep appearing. One of the founding members of our Society is with us at the 1986 Western Region meeting—Dr. William Snyder. As the International Historian, Ralph Shugert, said so well in the June 1986, *Plant Propagator*, "No single member of our Society has had more input in the guidance of this unique International Board, as the Society's only

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member who has sat on every International Board meeting since we became an International Society."

But what about *before* we became international? Historian Ralph, at the 1980 Western Region meeting in Anaheim, told us that our Society had its roots in an earlier organization known as, "The National Association of Propagating Nurserymen". Formed in 1919, the name was changed in 1927 to the "American Plant Propagators' Association". The constitution specified that membership was strictly limited to nursery firms engaged in the propagation of nursery stock for lining out in nursery rows for distribution within the United states, ONLY! No export—no scientists, extension agents, or florists allowed! The 12th and final meeting was in Detroit in 1931. It did not reconvene again, due to the severe downturn of the economy. Some say it failed because it did not promote free exchange of ideas.

At the inaugural meeting of the Southern Region, Jim Wells reminisced about the founding of our Society: "Way back in the summer of 1951 I received a letter from Ed Scanlon, Commissioner of Shade Trees, Cleveland, inquiring whether or not it would be a good idea to start a plant propagators' society. I said, YES! He apparently received affirmative replies from a number of people and so he called the first inaugural meeting held in the Senator Hotel in Cleveland early in December, 1951. There were between 75 and 80 people there. A number of interesting papers were given and, as far as I know, the first written paper on the propagation of rhododendrons from cuttings was given at that time. The thing that stands out most in my mind about the meeting, was that we spent the whole time arguing. There was a committee formed, and it argued all night about how the Society should be organized. I wanted the organization to be called the Plant Propagator's Guild, but nobody wanted a guild—this was un-American. The arguments were really about what the membership requirements should be—I wanted it to be a Society in which the voting members had some knowledge. You would have to be a practicing propagator for at least 10 years. This was too long—5 years was finally agreed upon. We also wanted to unlock the "locked greenhouse door" to guarantee a free exchange of information from one member to another."

Jim Wells continued, "We therefore required that a person should have experience, but we didn't eliminate the person without it—that was built in later with the introduction of the Junior Member, so that he or she could come along and learn, but the main structure of the Society was built around people who had knowledge and who would regularly share it. Being Doubting Thomases, we wanted proof people had, and would, share with each other; this has been developed over the years until now we have a system whereby you are required to produce, in writing, three sponsors. These sponsors have to take the trouble to state on a form provided

by the Society that the candidate is known to them personally and that the candidate does meet the membership requirements of the Society. This is not just a casual requirement. Where you work or where you come from has no bearing; it is you—the propagator—who is the important consideration; it is what you do, what your knowledge is, and how much you are willing to share your knowledge with other people that counts."

Everyone went home from that meeting without much having been decided. A portion of that first group met the following summer in Detroit and elected Jim Wells president, commissioning him to carry out the establishment of the Society.

In his tribute to Dr. Snyder in *The Plant Propagator,* Ralph reminds us that of the 9 original members of the organizing committee, 3 are still with us carrying honorary membership in the Eastern Region. These founders include Dr. William Snyder, Dr. L. C. Chadwick, and Mr. James S. Wells.

After initial action in the summer of 1958, instigated by Phil Barker and Hudson Hartmann, followed by a meeting in Davis, California in 1959 of about 50 West Coast plant propagators, a committee appointed from the Plant Propagators' Society met at Asilomar, California, on October 14–16, 1960. About 150 people attended that organizational meeting of what would become the Western Region of the IPPS. Mr. Jim Wells delivered the keynote address, and Dick Fillmore, in his opening remarks said, "The Plant Propagators' Society has meant a great lessening of professional loneliness." Donald J. Hartman of Leonard Coates Nursery was elected first president, serving in 1960–61.

In 1961, at the 11th annual meeting of the Plant Propagators' Society in Washington, D.C., the membership approved the formation of an International Society, and Harvey Templeton, Jr., was elected the first President, with representatives from both Eastern and Western Regions serving on his Board.

How did Regions outside of the North American continent develop? This was touched upon by Ralph Shugert in a paper given at the 1982 Western Region meetings in Hawaii. He reported that in the minutes of the International Board meeting in Anaheim, California in 1966, a letter from Jim Wells asked for the Board's attitude regarding forming chapters in other parts of the world. After due discussion, President Bill Curtis, with the Board's approval, directed Secretary Snyder to draft a reply indicating that the responsibility of forming such a Region would rest entirely upon the Society members residing in such areas and the interest they might be able to generate in developing sufficient potential qualified members.

The first meeting of the Region of Great Britain and Ireland was on September 18, 1968 with Brian Humphrey elected as President. Once again, Jim Wells gave a keynote address. International Presi-

dent, Pete Vermeulen, attended the 2nd meeting in 1969. In 1973, in addition to the International Board, over 140 overseas members and family enjoyed the pre- and post-conference tours and hospitality of the GB&I Region, further enhancing the international aspects of the society.

Next came the New Zealand group. The move to start a chapter there was initiated by Jim Wells in correspondence with Mr. Ellaby Martin, of Hamilton, New Zealand. The first meeting was held in September, 1972, at the University of Waikato, in Hamilton, and Mr. Martin was elected their first President. A good account of the inaugural session is given in Volume 23 of the IPPS Combined Proceedings.

The first meeting of the Australian chapter was held in October, 1973, in New South Wales. Jim Wells was once again the keynote speaker, and Edward Bunker was elected the first president.

The newest Region to form is the Southern Region. The first meeting was in December, 1976, in Mobile, Alabama, where two speakers addressed the question, "What is the IPPS?" These speakers were Bill Curtis and Jim Wells. The first president was Charlie Parkerson.

I would like to close with a quote from a talk given by Jim Wells at the first meeting of the Society, 35 years ago. "The plant propagator, the person who originates plants of all kinds, is the cornerstone upon which all other parts of this vast industry depend. Without him, without his work and his products, there would be no horticulture industry." In the IPPS, we have a unique, dynamic international society.

Get involved with your Region. Support it in the years ahead, and together we can make it one of the best known and most effective horticulture organizations in the world!

WHERE FROM AND WHERE TO . . .

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For the next few minutes, I invite you to join me in doing something rarely done at these meetings. I invite you to take this opportunity to dream—to look at where the nursery industry and plant propagation have been—where from. This look will not be sharply focused—rather it will be somewhat out of focus and somewhat directionless so that the essence of what was there will seep into our thinking without conscious direction.

Then, I want you to join me in directing this receptive mind forward—to where we are going—where to? In preparing for this discussion, I wrote several colleagues inquiring of their thoughts on where the industry is going and what it would be like.

> "My dreams . . . do not extend 25 to 50 years ahead. Yours probably do not either . . ." wrote Professor Elton Smith of Ohio State.
>
> "One thing is for sure, the mule and Ga stock plow . . . is not going to be a part . . ." wrote Professor Fred Perry of Auburn University.
>
> More of the same, others responded. If it is to be more of the same, it will probably will be with more emphasis.

TAKE YE SOME WILLOW AND CATTLE DUNG . . .

It is humbling to look at the past . . .

Marcus Porcius Cato describes how to graft trees in his book "On Agriculture." The time is spring, the materials include a split of willow, a hard stick and a stock mass consisting of "clay or chalk, a little sand and cattle dung . . . fit (scion) bark to bark (with stock). . . . Wrap the Greek willow thicker, smear the stock with the kneaded mixture . . ."

"The scions are pushed downward between the bark and . . . grafted stub is then thoroughly waxed." This is from PLANT PROPAGATION by Hartmann and Kester.

Cato's works were written sometime between 243 and 149 BC. Hartmann and Kester, third edition, is dated 1975. What has changed over 2200 years? We use nails rather than willow splits to secure the graft. We use grafting wax rather than a mixture containing cattle dung. We do not cover the entire graft with leaves and tie them into place.

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Let me add a couple of other seemingly unrelated facts or opinions . . .

Many years ago, one of my professors said—perhaps in jest or was he serious—that he almost discovered plant auxins as he studied the stimulating effect of animal urine on plant cells.

Older books on horticulture contain references to the stimulating effect of liquid manure on plant root growth. As recently as the 1950's, the practice of applying liquid manure to potted plants was carried out by many growers. Admittedly, many of these growers trained in the traditional ways and may have lacked "scientific basis" for their practices.

The stimulating effect of extracts of willow on rooting of cuttings has been documented by competent scientists, both academic and practical.

We are aware of the inhibitory effect of sphagnum moss on microbial growth. Recent studies by plant pathologists seem to demonstrate the effect of organic matter other than sphagnum on inhibiting root rots.

Without question, the grafter is more productive when we nail in the scion and coat everything with grafting wax. Additionally, everything is much neater. Imagine how many of us could tie willow splits to keep scions in place. So, not many of us will want to go back to tying the graft with willow splits and coating with a sticky mass of . . . however, there are some questions which could lead to . . .

Was there a stimulating effect on cell division and graft union by the use of willow splits?

Was there some effect from the cattle dung?

Did the cattle dung serve to inhibit diseases and other harmful organisms?

Witches brew or wives tales, not worthy of serious consideration, let alone scientific research? I need only remind you that Nurse Seed Grafting resulted because Professor Moore of Auburn University wanted to investigate whether there was any truth in the tale that inserting a grain in the base of grape cuttings stimulated rooting of those cuttings.

Where to . . .

TAKE YE SOME AGAR . . .

". . . we will be refining tissue culture and developing shortcuts . . ." predicts Paul Bosley, Sr. regarding the future of the nursery industry. So, also, says Bruce Briggs, "New cultivars may be created by genetic engineers involving some tissue culture . . ."

If cattle dung was necessary in grafting trees in Rome during the 2nd century BC, so then agar may be necessary in the 21st cen-

tury in the United States. Tissue culture has had a tremendous impact on agriculture. Genetic engineering has had more of an impact on medicine than on agriculture. However . . .

> Can graft incompatability be overcome by genetic engineering and tissue culture? Already, we can isolate numerous mutants of plants by tissue culture procedures that permit single cells to form entirely new plants. The same techniques, coupled with deliberate exposure to diseases or various stresses such as salinity, have isolated cultivars with disease resistance or tolerance to stresses. Can the technique be applied to rapid selection of understocks that are tolerant to the stresses and resistance to the diseases, at the same time becoming compatible with the scion? If dreams are where scientific research and subsequent papers begin . . .
>
> Where to . . .

TAKE YE A LITTLE BLACK BOX . . .

When plant explorers left England, France, and the other countries in the 1600's and the 1700's, they only expected that their reports and plants would speed along as fast as the wind. What a difference today when we can send the entire text of our proceedings electronically in a few moments to locations on the other side of the world, and we do not have to even type the words. Black boxes will read the pages, transmit the words, pictures and charts, and even reproduce the page at the destination, including all of the errors.

Today, black boxes can control the environment within buildings, including greenhouses, and control the scheduling of irrigation and pest control to fit the needs of the plants.

Today, black boxes can give us more paper and information that we care to have.

Computers and microprocessors are changing the way we gather and handle information of all sorts, but the speed of comprehension by people, the speed of understanding the message as contrasted to hearing the words has not changed.

Where to—people will be necessary to make decisions. To do so, they must understand and comprehend.

Where to—someday, all of the information needed for the culture of a specific crop, or the propagation of plants will be stored in computer memories, just as the information is stored in your memory and mine now.

Where to—there already exists programs for computers that will make us better spellers. The computer beeps when we spell a word incorrectly. Programs even exist to make us better writers. At least we will follow the rules of those that made up the program. The trouble is that it would make all writing the same. The Gettysburg Address and Mark Twain's "The Adventures of Tom Sawyer" failed

to meet the criteria of good writing according to this computer program.

Where to—we still will have a space for the Mark Twains of the future.

TAKE YE SOME IDEAS AND SOME SOLUTIONS . . .

". . . hoping you can expand, realizing nurserymen look at the situation differently than you research people." So commented Bruce Briggs in his wonderful response to my query about the direction of nursery and propagation in the future.

Research people everywhere seek ideas. Professors and academicians everywhere want ideas around which research can be conducted, around which discussions can occur. In the process, numbers are produced and the validity of the numbers and the resulting conclusions are debated.

Nurserymen are seeking solutions to problems.

Where to—we will continue to have the freedom to do things badly. We will continue to have the freedom to fail, to create and to invest. We will have the freedom to reap the rewards of our individual efforts.

I DARE . . .

Sometimes it is the poet, not the scientist, the doctor, nor the futurist that places our minds in the proper mood.

> George Bernard Shaw—"I dare to dream of things that never were . . . and say . . . why not"?

This has been but a sampling of a large mass of information that floats around. "A lot of what you talked about is not scientific," I can hear many academic snobs snort. "It's too empirical," I hear others. "It would not stand up to peer review" would be the ultimate putdown by some.

It is not the intention of this discussion to point out the road. Rather, it is to dream of where we have been and the dream of things to come. How many of us will be willing to say with George Bernard Shaw, ". . . why not"?

TRENDS IN AGRICULTURAL RESEARCH

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We are in a very crucial period as we look at the future of American agriculture and examine the promise of science. On one hand we can look at the past 30 or so years and be impressed with contributions that science and technology have made to agricultural productivity. Let us look for a moment at the history of American agricultural productivity as shown in Figure 1 from an Office of Technology Assessment Report (3). We see that it can be divided into four major periods—hand-power, horse-power, mechanical-power and finally, science-power. The transitions from one form of power to another were marked by the Civil War, World War I, and World War II.

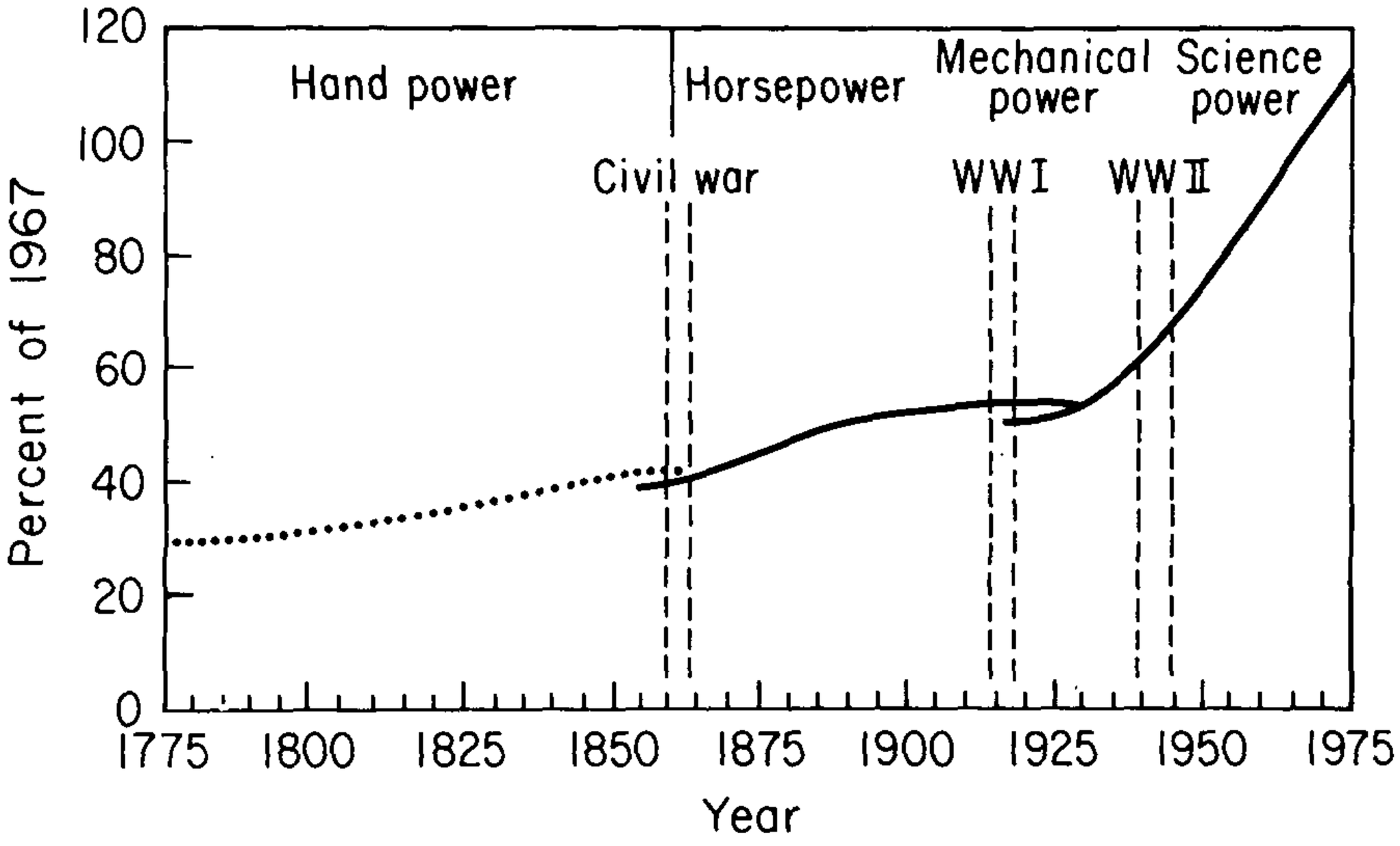

Figure 1. U.S. agricultural productivity growth during the past 200 years

From Figure 1, it is clear that during the period called "science power," or more correctly, the period of science and technology, is when dramatic gains in productivity were achieved. Evenson, Waggoner, and Ruttan, in their article, "Economic Benefits from Research: An Example from Agriculture," provided several indices to measure productivity from the 1950s to 1978 (1). As shown in Figure 2, land productivity increased at a rate of nearly 2 percent per year. There was a dip in productivity in the early 1970s, when in

part, less productive land was removed from the soil bank in response to world grain shortages. The index of labor productivity is widely used in agriculture and industry and, as shown in Figure 2, since 1950, labor productivity has grown far more rapidly in agriculture than in the nonfarm sector. Total productivity, which is calculated by dividing the index of farm output by the index of total farm input, has also grown rapidly since the 1950s. According to Evenson *et al.* (1), in the 30-year period from 1949 to 1979, scientific and technological innovation increased agriculture output by 85 percent with no change in the aggregate level of agricultural input.

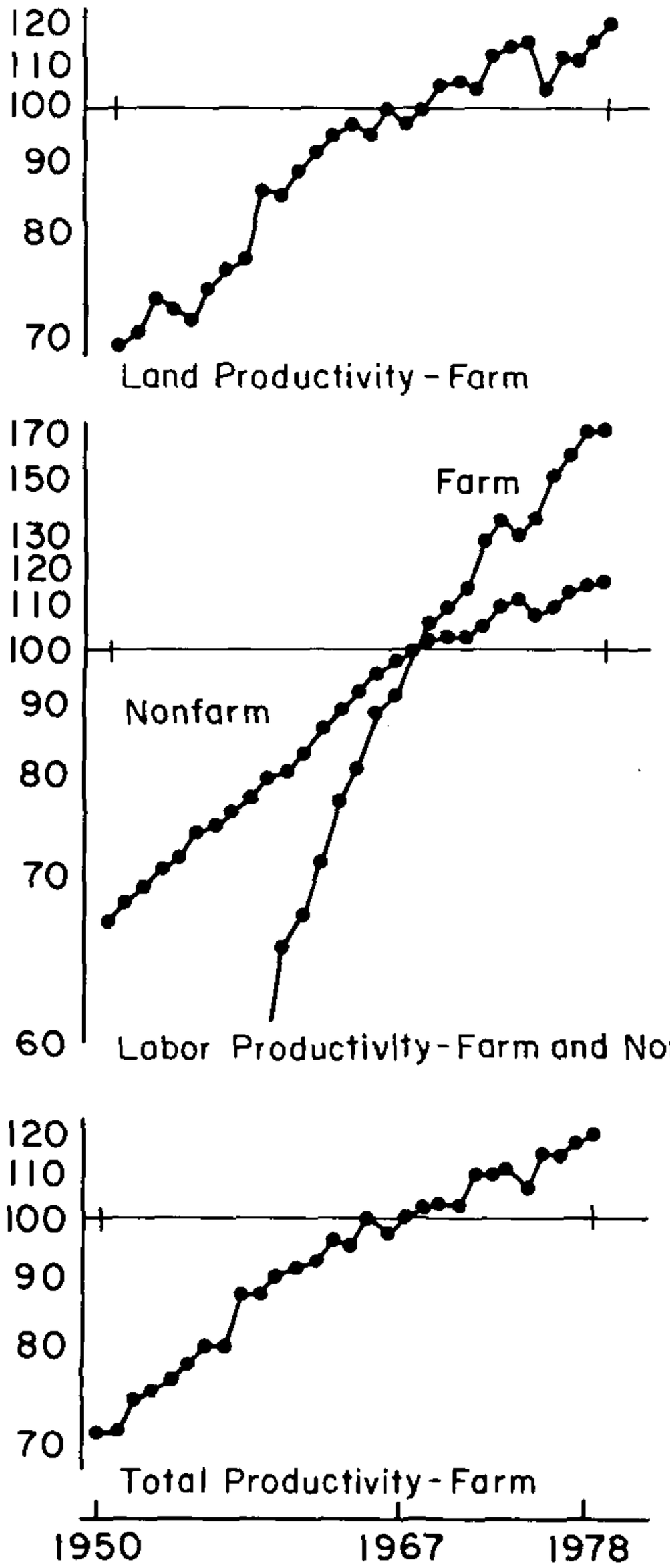

Figure 2. Increases in land, labor, and total productivity from 1950 to 1978 (1).

Another frequently used index is that in 1900 one U.S. farmer supplied seven other people with food and fiber. Today the average U.S. farmer supplies more than 75 people and, in view of the current economic conditions facing American farmers, the ratio of people fed per farmer will continue to increase. I should point out here that science and technology cannot be given all the credit, or blame, for increased productivity. There are external forces such as farm policy, tax incentives, or shortages of inputs that play a major role in the adoption of new technologies developed through science.

A most dramatic example of the interplay between science and government policy is seen in the tremendous growth of agricultural productivity in China. In seven years China has gone from a country which faced shortages in grains and fiber to where it is now able to export both. The agricultural sciences in China have been extensively rebuilt since the Cultural Revolution through government investment and World Bank loans which have permitted the exchange of scholars and the renewal of the research infrastructure. But, equally important was the government policy which changed the production unit from the commune to the individual household. After a household meets a specified quota of crops or animals, the surpluses can be sold to the state at higher prices or sold on the open market. The combination of science and technology and incentive has facilitated an agricultural revolution in China.

But what have been the costs of increased productivity. Farmers in the 1930s were largely self-contained, but now purchase about three-fourths of their production staples, such as pesticides, machinery, fuel, genetically improved cultivars, and fertilizers from outside sources. Extensive purchase of production supplies from nonfarm sources requires that farmers maintain adequate cash flow or be able to obtain operating credit. This situation makes the farmer far more vulnerable to economic externalities while still being subjected to the vagaries of weather and the marketplace. Therefore, critics of technology contend that, in part, the current depressed state of American agriculture is caused by the dual effects of excess production resulting in low prices and high costs of achieving that production through the use of agricultural chemicals and energy consuming equipment. In addition to economic effects of technology, critics also point to environmental problems such as soil erosion, the pollution of surface and ground water by pesticides and fertilizers, and the depletion of aquifers and the salinization of surface soils through irrigation.

You may ask then, what is the promise of science and its application? My view is that potential impact of science is as great as it was at the beginning of the period of "science power" in the 1950s and perhaps even more exciting. Advances in science are essential if we are going to be economically viable and be able to

compete on international markets. We must continue to increase our efficiency of production. That does not mean producing more—unless there is a demand—but it does mean producing the same for less cost providing greater economic viability or competitive advantage. Furthermore, we not only have to reduce costs, but we have to assure ourselves and the public that we have a sustainable form of agriculture in which we conserve our natural resources and eliminate adverse effects upon the environment, and deliver a safe product.

What kind of science can promise these ambitious goals? One possibility is the new biotechnology or genetic engineering.

Biotechnology is a word that probably has no equal in meaning so much or so little to so many. However, it does convey an exciting concept in that we have new tools and technologies enabling us to modify living organisms with a precision not formerly possible and to combine traits from organisms that are unrelated or incompatible.

Biotechnology, broadly defined, includes any technique that uses living organisms or parts of organisms to make or modify products, to improve plants or animals, or to develop microorganisms for specific uses (2). Using this definition, biotechnology can be said to have originated at least 10,000 years ago when the transition was made from a food gathering society to one which cultivated plants and animals. The early farmers selected crops and animals for desirable traits which improved productivity or adaptability to a given environment. Thus, the earliest farmers were taking advantage of genetic variability inherent in plants and animals. They also developed the biotechnology of fermentation to produce wines, beer, and sauerkraut and the use of yeast to make bread. More recently, microorganisms have been used to produce antibiotics for the control of disease and other substances such as interferon and insulin.

So what, then, is new and the basis for all the excitement? What s new are two separate developments each having its genesis in the 1940s. I will briefly trace each development and show how they have now come together, bringing us to one of the most exciting times in the history of agricultural science.

The first accomplishment was the development of hormonal control of shoot and root regeneration in tobacco callus cultures and the subsequent discovery of cytokinins by Skoog and his coworkers in 1948. A practical use of tissue culture was the production of virus-free plants from meristems. Using this technique, Morel, in 1964, found that shoot tips from cymbidium orchids proliferated into masses of protocorms which could be divided and recultured to produce new plants. In the same year, F. C. Steward, a Cornell University faculty member, reported that carrot callus produced in tissue culture could be separated into single cells and that a single

cell could be regenerated into a whole plant. Thus, the concept of "totipotency" was introduced—that is, a single cell contains all the genetic information needed to form a total plant. As scientists began to master the art and science of plant tissue culture, increasing the number of plant species that could be regenerated from single cells, they found that there were some unexpected variations in the progeny, or what is called "somaclonal variation." It is now recognized that the rate of mutation increases and can be expressed more easily when culturing large populations of plant cells. The selection pressure can be increased by placing the cell population under conditions of stress, such as the presence of high salts, a toxin from a disease-producing organism, or low temperature. It is possible, therefore, using the culture of cells or cell protoplasts to speed up the process of finding and isolating genetic variability. Plants can be selected which are more adaptable or resistant to disease in a shorter time and in less space than conventional approaches require.

Cell and tissue culture also made it possible to begin asking some of the fundamental questions about differentiation. What are the mechanisms regulating the expression of genetic information contained in the cell nucleus? What causes a group of cells in an undifferentiated mass of callus to become organized into a shoot or root? What causes a single lettuce cell to develop into an embryoid and eventually into a plant? There is still much to be learned from and about cell and tissue culture. I refer to tissue culture as an art and a science because, at this point in time, both are required for success. The number of species that can be regenerated from single cells is still unlimited, and the traits selected from somaclonal variation are not always stable and the genetic basis for the variation is not completely understood.

Let us now turn to the other area of science which was evolving during the same time period, often in conjunction with health-related research, using micro-organisms as a research tool. This is the area of recombinant DNA technology. Starting in the 1940s, Oswald and others presented evidence that genes were made up of DNA, deoxyribonucleic acid. In 1953, Watson and Crick described the three dimensional structure of DNA, and later the process of transcription and translation was established.

How then does an individual select a single gene from among the many thousands or more genes occurring along the strands of DNA that make up a chromosome? In the 1970s, scientists found in bacteria restriction enzymes which cut DNA strands into pieces thereby eliminating foreign DNA. The restriction enzymes each have a unique specificity for nucleotide sequences, and therefore, they will cut the DNA strand only when it locates a specific sequence.

By selecting the proper restriction enzyme, it is possible to remove a specific gene from the donor DNA molecule. It is also pos-

sible to use the restriction enzyme to open a plasmid (circular strands of DNA) and then insert into this opening the gene removed from the donor DNA. If the plasmid is inserted into a bacterium and the gene is expressed, large amounts of the specific protein will be produced following manipulation of the bacteria.

In addition to cloning genes to produce specific proteins, the plasmid may be used to insert a gene into a higher plant. The methods available to insert the new genetic information into a plant include direct insertion into a protoplast, the use of a virus, and the use of a plasmid from the crown gall bacterium, *Agrobacterium tumefaciens*, as a vector. After a gene is inserted into a cell genome, tests have to be conducted to see if it is expressed. If the trait is expressed, the next step is to regenerate a plant from the transformed cell and determine if the foreign gene functions in the intact plant and in subsequent generations. It is at this point that the two areas of science come together: the merger of recombinant DNA technology and plant and cell culture.

How is this technology being put to use? Recently, scientists at Calgene in Davis, California developed a strain of *Salmonella* which is resistant to the herbicide "Roundup" (Glyphosate). The gene responsible for the resistance was isolated, identified, and inserted into tobacco and tomato cell genomes. The regenerated plants are expressing resistance to the herbicide. This accomplishment may be among the first of the commercially important applications of biotechnology in the plant sciences.

Another application of biotechnology which appears to be close to commercial application is the genetic modification of *Pseudomonas fluorescens*, a bacterium which inhabits the soil of midwestern corn fields. The Monsanto research laboratories have been able to transfer the gene from *Bacillus thuringiensis* that regulates the production of a protein that is toxic to insect larvae. *Bacillus thuringiensis* is already used to "biologically control" tomato hornworm. It is planned to coat corn seed with the genetically modified *Pseudomonas fluorescens* so that it will produce a natural pesticide in the corn field soil and control black cutworms.

A third application that is ready for field testing is an ice-minus bacteria, a bacteria from which a single gene has been removed. Dr. Steven Lindow at the University of California has been working with *Psuedomonas syringae*, a bacteria which lives in the epidermis of many plant species including beans and potatoes. The naturally occurring *Psuedomonas syringae* releases a substance which serves as the nucleus for ice crystal formation as the temperature drops to freezing. The ice crystals pierce the epidermal cells and cause injury. It was found that a gene could be removed and the modified bacteria no longer caused the ice nucleation. Greenhouse tests indicate that if the wild strain is replaced by the genetically modified

bacteria, the plants will tolerate exposure to temperatures as low as 22°F without injury. Naturally occurring strains of *Psuedomonas syringae* are used to enhance artificial snow making at ski resorts.

Examples of other research that is underway includes a dwarfing gene for fruit and nut trees, a gene which increases salt tolerance in organisms, and attempts to increase the efficiency of bacteria which biologically fix nitrogen.

In the area of post harvest physiology, a gene which regulates tissue softening have been isolated. If the expression of the gene can be regulated, it may be possible to extend the quality of fruits.

Much of the current research in biotechnology is designed to reduce our dependency on agricultural chemicals through the development of disease and insect resistant varieties, to increase the range of biological nitrogen fixation, to provide greater resilience to environmental stress, to develop new crops; and to preserve genetic diversity in plants. If we can develop genetic resistance to pests or increase the number and effectiveness of biological control organisms, we should be able to reduce production costs as well as reducing adverse effects upon the environment. It is even possible to correct problems such as pesticide disposal sites by selecting or genetically modifying bacteria which can biologically degrade the pesticide residues.

Although we are in a very exciting time in terms of research trends, we are also in a very challenging time. In view of surpluses, some growers are saying we should stop research that leads to increased productivity. As I have said earlier, research does not lead to surpluses; it is grower decisions to increase the production of more profitable cultivars or techniques that lead to surpluses. Second, the public is skeptical about new advances in technology. You may have read or heard about the concerns expressed about the field testing of the ice-minus bacteria. The experiments have been blocked for several years through protests and legal actions in the courts.

What can be do to head off these restrictions to free inquiry? First, we must be sure our own house is in order. Beyond the traditional objective that technology must be profitable for the user, we must *continue* to apply additional criteria in agricultural research and development. We must also be certain that society is aware of what criteria we are using. Included are: 1) energy efficiency, 2) acceptable long-range physical impacts on the environment, 3) that we have studied and minimized health and safety risks, and 4) that we are aware of any social consequences and that they will be acceptable to society, or we must find ways to address the expected social costs.

Second, we must be sure the research that we do is necessary and that if there are risks, such as the possible release of a pathogen, that all possible precautions are taken. The fact that the scientific

community established its own stringent restrictions at the beginning of recombinant DNA research gave assurance to a majority of society that we placed a high value on their safety and concerns. In return, there was self-policing rather than overregulation from outside groups.

Beyond these activities, we have a special responsibility as educational institutions to do all we can to ensure that our graduates, whether from agriculture, engineering, or the liberal arts, have scientific and agricultural literacy. Part of the current problem is due to a lack of background on which to base rational decisions. We are attempting to do research in an environment in which the public is underinformed, misinformed, or wholly ignorant of the issues, but at least a part of that public wants to play a role in the decision-making process. This is perfectly appropriate in a democratic society. However, we must educate the public and the policy makers about our research and the benefits to society and to assure them that we are aware of the risks and the costs as well as the benefits. Then their participation in the decision-making process will be based on knowledge rather than ignorance.

The concerns I have given are not simply California anomolies or issues that will go away. Unless we counter our attackers with equally articulate and active programs of information, society will in fact have placed scientific inquiry on the endangered species list to the detriment of all. As Congressman George Brown from California has said: "Misinformation can be enacted into law!" The promise of agricultural research is truly great. But we have an additional responsibility today to help insure that the promise is realized.

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EARNING WHILE LEARNING—AN EDUCATIONAL APPROACH

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Employers of today's Ornamental Horticulture graduates expect more of their new employees than just technical knowledge. They seek people who not only can pull their own weight, but who have leadership ability and experience in the industry. Most of the students in our horticulture program at Cal Poly have had some applicable experience. They have worked in nurseries, done landscaping, or been active in high school or community college horticulture programs. It is up to us to provide them with the technical knowledge and at the same time give them a greater depth of experience. This can be done in several ways—through part-time employment during the academic year, through industry-sponsored summer employment, through industry internship, or through production and sales experience.

Many years ago Cal Poly found its niche in agricultural education in California through educating young people for immediate employment in agricultural production and management. The "Learn by Doing" philosophy espoused by our long-time president, Julian A. McPhee, involved an upside down approach to teaching as compared to that of the traditional college or university. Our students began taking their major courses during their first quarter on campus rather than first taking two years of general education. The reason for this approach was two-fold:

(1) Since many students do not complete four years of college, they are learning practical applications from the very beginning. They are developing marketable skills that should make them more employable if they drop out after one or two years.

(2) By an early exposure to the practical aspects of agriculture students will see more need for the theoretical and scientific work as it comes along.

Last year, in Rockhampton, Queensland, I spoke to the IPPS Australian Region about Cal Poly's Agricultural Internship Program as a means of providing experience (1). Today, I would like to describe our Agricultural Enterprise Program—a program in which the Cal Poly Foundation finances our qualified agriculture students in setting up their own business enterprises. With faculty guidance the student selects, researches, produces, and markets an agricultural commodity, sharing in the profits from his labor.

Of the ten departments in our School of Agriculture, six are involved in Agricultural Enterprise operations. This program

[1] Professor Emeritus

requires planning, space, and facilities, but the most important ingredient in its success is a dedicated faculty. This means someone who is willing to be there on Saturdays and holidays, who is firm and fair, and who will guide but not dominate the students.

Examples of typical Agriculture Enterprise projects might include:

POULTRY DEPARTMENT:
- Laying project
- Meat bird project

CROP SCIENCE DEPARTMENT:
- Certified oat seed
- Fresh market corn

FOOD SCIENCE:
- Chocolate covered bananas
- Blackberry jam

DAIRY SCIENCE:
- Milk production
- Ice cream manufacturing

ANIMAL SCIENCE:
- Thoroughbred training
- Cow-calf operation

ORNAMENTAL HORTICULTURE:
- Bedding plants
- 4-inch color plants

Each year, approximately 25% of our 3800 agriculture students are involved in this production and marketing experience. Because of limited space and faculty for supervision, we consider involvement in an Enterprise Project a student privilege, not a right. To be eligible, a student must have completed two academic quarters with satisfactory grades and be able to convince his advisor that he has the dedication and tenacity to follow through.

As a 40-year faculty member and administrator at Cal Poly, I am convinced that the Agricultural Enterprise Program is one of our most effective teaching tools. This has been borne out time and again by testimony from our graduates.

Some advantages to the student include:

1. An opportunity to apply knowledge gained in class to a real life situation.
2. An opportunity to earn money.
3. An opportunity to experience the work ethic: to demonstrate dependability, persistence, and the budgeting of time.
4. An opportunity to have a real look at human relations: Your best friend may not be the best business partner; a verbal contract doesn't always assure a market.
5. An opportunity to learn merchandising and sales.
6. An opportunity to deal with minor or novelty crops in greater depth than can be done in formal classes.
7. Learning to time a crop for a specific market.
   Need for the proper environment. Typical problems could include:
   Light pollution of a poinsettia crop?
   What happens when the heat goes off?

How to compensate for a month of rain?
Deer control?
What happens when spring holiday comes during Easter week?

8. Gaining valuable experience toward career employment.

Some advantages to the department include:

1. A much wider range of crops than could be justified by state funding alone.
2. Greater cooperation of the horticulture industry in furnishing plants, materials and markets.
3. Successful projects often lead to minor research grants.
4. Information gained leads to Senior Thesis and Special Problems studies.
5. Projects provide good publicity and public relations.
6. Project involvement generates faculty positions.

Up to this point all of my comments on the Agricultural Enterprise Program have been positive. However, there are also some potential problems, including:

1. Public relations.
   Perceived competition with local businesses.
2. Accountability.
   Need for accurate records and handling of money.
3. Supervision time for faculty and staff.
4. Competition for space and facilities.
   What priority does this program rate?

SUMMARY

While the Agricultural Enterprise Program has worked well for Cal Poly, it may not necessarily be applicable on other campuses. It demands strong backing of the faculty and staff as well as the university administration.

It is one of the teaching tools that is effective as part of a vocationally oriented teaching program. The experience ties in well with classroom teaching, industry internships, field trips, and close communication with the horticulture industry. It provides the student with real life experience in production and sales, enabling him to begin his full-time job with a running start.

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BRUCE BRIGGS: How can we work with other countries so that as the IPPS grows larger we can continue as a united organization and not just a bunch of independent groups?

PHIL PARVIN: The basic philosophy of IPPS is "to seek and to share" and, as other countries consider joining us, they must adhere to this precept and we must help them learn the philosophy that has worked so well so far. It seems that English must continue to be the language used in our publications.

RICHARD CRILEY: I would like Phil Parvin, as IPPS President, to comment on the relationship of the IPPS and the Ornamentals Sections of the International Society for Horticultural Science (ISHS).

PHIL PARVIN: IPPS gives strong moral support to any of the Regions who wish to co-sponsor a symposium jointly with ISHS. This was done so well in the case of the Australian Region which did co-sponsor such a meeting. However, the International Board of IPPS does not have a fund to financially support such cooperation. We would welcome any suggestions as to how we should support such joint meetings.

HOWARD BROWN: I would like to ask Dr. Tukey to comment on the methods they use at the Canter for Urban Horticulture at the University of Washington, Seattle, for raising funds to keep their new program going and expanding.

HAROLD TUKEY: Our financial support comes mainly from individuals rather than corporations, but it takes a lot of hard work also. Nurseries in Washington have also given us strong support, both financially and morally.

DENNIS CONNER: Dr. Tukey, could you elaborate, too, on the role of the ISHS in relation to the IPPS?

HAROLD TUKEY: The International Society for Horticultural Science sponsors every 4 years an International Horticultural Congress. The last one was in Hamburg. Next week at Davis, California, such a Congress will convene with about 4000 participants attending from all over the world. This is the largest attendance ever, and only the second time the Congress has been held in the U.S. ISHS has commissions and sections but do not have large funds to promote meetings. It just aids in facilitating sectional meetings all over the world, but particularly in Europe. The ISHS and the IPPS are planning to jointly sponsor a symposium on the propagation of woody plants to be held in Pisa, Italy in September, 1987.

PLANT PROPAGATION IN AUSTRALIA

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The population of Australia is just under 16 million. Of that, nearly 10 million or almost ⅔rds live close to the East Coast—from Brisbane south to Adelaide. Of that 10 million, 8 million are in four state capitals (Brisbane, Sydney, Melbourne, and Adelaide). To further emphasise our skewed demography may I add that there are over 6 million people in Sydney and Melbourne alone.

From these figures you will understand that the significant market for greenstock, and indeed most other goods, is in the south-east of Australia. If I tell you that there are a further 1 million people in Perth you will also understand that the rest of the continent is not exactly crowded.

In Perth there are some excellent nurseries in the hot, dry climate that is ideal for much nursery growing. Fortunately for nurserymen in the Eastern States, Perth is remote, being separated from the rest of Australia by some 2,500 km of the Nullarbor Plains (nul arbor = no trees), though a small amount of high quality stock is sent east as back-loading on what would otherwise be empty trucks.

The wet tropics in "Crocodile Dundee" country around Darwin and on the east coast near Cairns provide hot, humid, glasshouse conditions in the outdoors. One grower even uses fans to draw air from under his shade covers. Brisbane, and the north coast of New South Wales, are ideal for growing house plants and, indeed, large quantities are shipped south by the local growers.

After these introductory remarks I will now focus on propagation in Victoria, my home State and the area with which I am most familiar. However, what I have to say about propagation in Victoria would apply generally, to Perth and Adelaide and, to a lesser extent, in the more humid climate of Sydney.

The climate of Victoria is similar to that of California. Hot and dry in summer, day temperatures are commonly in the nineties and most years have many days well over 100°F. Winters in Melbourne bring frost and some overcast foggy conditions. Inland the frosts are crisper and fog rare.

STRUCTURES

Although some new propagation houses have been built recently using glass, most nurserymen are favouring plastic houses of various types and constructions. Because of the extremes of climate (Melbourne is noted for experiencing all four seasons of the

year in one day) both cooling and heating are important. Extractor fans are common, so too are plastic tubes. All the traditional forms of heating can be found. In our own case we have turned an oil heater upside down and blow hot air under the benches.

I should add that we find a large range of Australian natives are more prone to fungal attack than most commonly grown ornamentals of exotic origin. For this reason we like fans moving air about and we tend to keep our propagation houses as dry as possible.

A novel glasshouse was designed by a commercial airline navigator who grows orchids. The design theory is based on the light transmission properties of glass; that is maximum light and heat is transmitted when the sun rays strike the glass at 90°, less and less light penetrates as the angle of incidence reduces.

To erect this type of house get out your compass then align the house to face due north—the direction of our midday sun.

The saw-tooth roof in this house is made from opaque asbestos cement sheeting except for the north-facing vertical glass which transmits a greater percentage of available sunlight in winter when the sun is low in the sky but tends to block its passage as the sun rises higher in the sky in summer months. The angle of overhang of the glass on the saw-tooth sides is designed to behave similarly in respect of sunlight striking the walls.

An interesting house was built by the South Australia State Government for its forestry people at a cost of around $120,000, of which $45,000 was spent on the solar heating. Heat from the collectors is stored in water that is circulated in pipes through the concrete floor of the house.

The theory is that there will be enough heat collected and stored in the warm months, supplemented with some winter sunshine, to provide heat in the cold periods. Production from this nursery consists of Australian native evergreen trees and shrubs in liners and, as such, would only need minimal heat to maintain at least some growth.

FOGGING

A limited number of fogging systems have been installed in Australia. In March of 1986 we installed a system using sonic nozzles of U.S. origin. These operate around 60 psi air pressure but they rely on a large volume of air as a result of which we require a 7½ h.p. compressor to run the 12 nozzles installed in a 4 bay house measuring 80 ft × 60 ft. The water pressure is around 5 psi.

We had a lively discussion at our 1986 I.P.P.S. Conference in Adelaide about the temperature which fog houses could be allowed to reach without damaging cuttings in almost 100% relative humidity.

I personally had been introducing a minimal amount of ventila-

tion to prevent the temperature exceeding 95°F. A member from western Australia reported that he never ventilates his house (which not uncommonly reaches 117°F) with excellent results. We recognised that there could be a difference between ambient and plant tissue temperatures, but because high temperatures are sometimes sustained for long periods and because little, if any, evaporation occurs on the leaf surface, we assumed that tissue temperature would eventually approach that of the house. Unfortunately we did not have a plant physiologist with us who could explain what happens to cuttings in extreme conditions and our discussion was little more than speculation.

MEDIA

Most growers are using soil mixes comprised of bark and or sawdust, often supplemented with a small proportion of sand or sandy loam. Slow release fertilizers are normally used.

In Victoria, many nurseries pasteurise or sterilize to some degree and, indeed, a lot of Dr. Ken Baker's work was developed in Melbourne. At Plant Growers Australia, we use an air-steam mix to pasteurise cutting media. The sandy loam fraction of our potting and tubing mixes is pasteurised using live steam blown into slowly turning concrete agitators. Bark and fertilizers are added later. Suppliers of pre-mixed media to the nursery trade rely on methyl bromide treatment.

PROPAGATION

Our production centres around evergreen ornamentals, but excludes azaleas, rhododendrons, and camellias. We grow over 400 cultivars per year, of which about 300 are Australian natives.

About 92% of our production is from cuttings, 6% from seed, and 2% from tissue culture.

In cutting propagation, most material is collected from our own container plants or other clean stock. It is cut, stripped, soaked in fungicide, rinsed and drained, dipped in powder or liquid hormone and then stuck in community trays. Media used are sand and peat, perlite and peat, and more recently trials using perlite and fine composted pine bark have shown favourable results for some plants.

We have done many trials with media and hormones over the years and have found that in a 3:1 perlite/peat medium and a 4000 ppm IBA in talc hormone to be suitable for most of the plants we grow.

Many cultivars are placed on beds heated by electric cables. The trays are subsequently moved onto wire mesh benches for hardening off and, hopefully, aerial root pruning.

We buy tissue culture plants in culture vessels, transfer both rooted and unrooted plantlets initially into a fog house. Seed is

raised in conventional misting poly houses.

A regular fortnightly fungicide program is carried out. All cutting and most tube stock are drenched or misted on alternate fortnights with different fungicides. Insecticides are used only when needed.

To promote uniform plant growth, tube stock is graded and pruned before potting.

MECHANISATION

Not only are wage rates high by U.S. standards, so too are the loadings for holiday pay, workcare, payroll tax, etc. As a result there is strong financial incentive for growers to mechanise production wherever possible. Potting machines are found in most production nurseries.

Our potting is mechanised and we also use a small tubing machine for transplanting a high proportion of the rooted cuttings from the community trays into 2 and 3 in. tubes. Cuttings with brittle roots are transplanted by hand.

INNOVATIONS

Peter and Lois Smith, whom many of you know, operate the Sunraysia Nursery, just over the river from Mildura on irrigation country that is an important citrus, grape, and stone fruit production area. Among other lines, Peter produces vast numbers of grapevine plants. For many years he has used techniques whereby he unites a scion to an unrooted rootstock and provides conditions in which the roots developed simultaneously with the graft union.

I found his latest method very exciting and he has agreed to let me tell you about it. Thin-walled plastic tubes measuring about 12 × 1 in., complete with interior root-trained ridges, are filled with a very lightweight cutting medium. The rootstock and scion are united with the help of a grafting machine and this two-part piece of wood is inserted half way into the plastic tube which, in turn, is placed in an appropriate environment for nature to take its course. Peter tells me that he has significantly reduced his production costs, but the good features do not stop there. When planting, the growers go into the paddock with a tractor-mounted sprayer rigged up to give a controlled waterjet which is used to blast planting holes. Another person takes the vine, runs a knife vertically down two sides of the plastic tube, which is then holding everything together, and places the plant with its roots still undisturbed into the hole.

After back filling, the two strips of plastic are gently removed. I am not experienced in grape production or field planting but the method captured my interest.

WEED CONTROL

Our annual nursery crop is about 1 million plants, grown in 6 and 8 in. containers. Very few are sold in less than 5 months from potting and the man-hours spent in weed control would be the equivalent of approximately 60% of one person's time over a full year.

The practice we follow can best be described as discipline based on a very simple premise, namely that the pot next door is the greatest source of weed seed, and we act accordingly. Indeed, we go a little further by preventing seeding of weeds anywhere in the nursery grounds. The boundary is fenced and where possible the outside area is slashed to minimise seed drift and prevent seeding anywhere in the nursery grounds.

Before new crops are put out, the bays are checked and granular herbicide is often lightly applied, though this becomes less necessary after a few years of no seed. Because we pasteurise all potting soil we initially eradicate all but hard-coated weed seed.

PLANT PROPAGATION IN NEW ZEALAND

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It must be recognised that the establishment of the nursery industry in New Zealand by those nurserymen who arrived in the first two decades of the colony's history involved experiences that tested their skills and abilities to the maximum. Very few of them arrived with possessions such as bank accounts or other tools of trade to establish an industry in this new country.

When one studies the early days of the New Zealand nurserymen, it appears that most commenced their business as market gardeners, slowly moving their production in varying directions to the market demands of their districts. Those pioneers who arrived with tree seeds, cherry stones, apple and pear pips, and other horticultural plants combined the growing of one and another and slowly made a beginning of an industry in New Zealand. This, of course, was only one part of the story, because along with the production of plants came the potential customers. These were the farmers grappling with the land and the new problems of a land that was just beginning. A problem to overcome was a shortage of cash, so a system of barter was adopted between the man who produced from the soil, and the merchant in his office and warehouse. In these

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early days of the industry, a man's word was his bond, and integrity and industry meant as much as silver and gold.

From the beginning of the settlement in the early 1840's, it was not until the age of refrigeration that New Zealand started to move from a struggling colony into commerce, and population growth commenced. This saw a new industry open up where fruit trees and the potential of their products could be shipped overseas to other profitable markets. Today we have an apple and pear export business which brings returns to the country measured in millions.

The distribution and selling of nursery plants in New Zealand has never been an easy process. This was particularly evident in the early years of the nursery business. In those days it was a free-for-all with people marketing wherever the need took them. Nevertheless, the future of the country and the desire for beautification is now marked by many monuments throughout the country in the form of magnificent tree specimens in parks and public domains, along with those in private gardens. Many of these have been noted by visitors from both New Zealand and overseas countries.

The New Zealand nurseryman and his propagation skill have earned him acceptance from the "trade" in many other countries. This has been proven more than ever over the last 10 to 20 years with the development of a sound export market for New Zealand ornamental plants and, especially, for some fruiting plants.

The climatic variations through our small country is vast, therefore the natural flora varies between the two main islands. Nurseries are spread throughout the main centres and are situated within the farming areas, supplying both shelter and specimen trees to the largely agricultural industry which covers much of our landscape.

Over the years we have seen a gradual move away from the general nursery which covered all lines from herbaceous plants, hardy woody plants, to bulbs and fruit trees, to more specialisation. This, in many ways, assisted the nurseryman but has brought about difficulties in the training of the student within the horticultural industry.

Training

New Zealand has been recognised, especially in the South Pacific, for the emphasis placed on its Universities and Technical Institutes, and now within our schooling, the training of horticultural students. We are very fortunate to have in New Zealand two universities that offer a range of both diploma and degree courses, the diploma being more practically orientated, to the scientist where degrees are available in horticultural science. In conjunction with this, spread throughout New Zealand many Technical Institutes offer comprehensive courses that cover all aspects of horticulture.

Over the past 5 to 6 years, with the recognition of horticulture

as a major export earner for our country, we have seen, in addition to Technical Institutes offering day-time courses, extra night classes being offered. More recently we have seen the introduction of horticulture into the schooling system, with exams being taken in the third year of secondary training.

Bedding Plant Production

The bedding plant industry is centred around several main areas throughout New Zealand: firstly, where large populations exist and Garden Centres operate and, secondly, in the areas where large scale vegetable production is carried out, for both local markets and the processing industry. New Zealand has a large fruit and vegetable base on the East Coast of New Zealand at Hawkes Bay, where one of the largest canneries in New Zealand operates. Within these areas are situated large producers of vegetable seedlings. Production is mechanised using plugs, as well as vacuum sowers to ensure quality, consistency, and the right product to the grower.

The Garden Centre industry within the main centres draws on large numbers of both flower and vegetable plants for the home gardener. The average New Zealander with his small piece of land adjoining his property, has always shown a keen interest in growing his own vegetables and flowers and, for this reason, the bedding plant industry has continued to prosper throughout New Zealand.

House Plant Production

Again this area of plant propagation is centred around large, modern, well-equipped house plant producing nurseries. Production has been of conventional means, both by seeds and cuttings but, more recently, the association of some of the larger operators with tissue-culture laboratories, both in New Zealand and Australia, has seen tissue-cultured plants entering the New Zealand market in large numbers.

From New Zealand has always been a keen desire to export house plants throughout the Pacific as well as to the Asian countries of Singapore and Hong Kong. Although not large by world standards, regular shipments are supplied to many plant shops in these areas. The difficulty that has to be overcome by all New Zealand producers irrespective to the product that he grows, is the distance he is from the market.

Field Production

Across the length and breadth of New Zealand can be found field production of ornamentals and fruit trees, as well as timber crops. In the central part of the North Island are large scale timber producing nurseries, both private and Government owned. These supply seedlings throughout the country; seeds are produced in seed orchards in the case of *Pinus radiata*. The production of roses and their acceptance on the market place has always been considerable

and, again, throughout New Zealand rose production has played an important role for the field producer.

The Taranaki district, with its ideal climate, soil types, and world recognition for its rhododendrons, has always been a centre for one of the largest nurseries, that of Duncan & Davies Limited. With its large-scale field production, it has supplied New Zealand with some of the world's best cultivars of rhododendrons and azaleas, along with a complete range of other field-produced crops. It also is one of the largest producers of conifers and camellias for the U.K. market.

Ornamentals

Propagation of ornamental plants within New Zealand is carried out as both small and large scale operations. The range is extensive depending on the climatic zones, moving from the top of the North Island with semi-subtropicals, down to the alpine areas at the base of the South Island. The range of products produced and the skills needed to be applied to such a wide flora range, test the ability of the New Zealand propagator to a maximum. This has always captured the imagination and interest of all horticultural visitors to New Zealand, and it is for this reason that we have seen a steady and expanding market for ornamental plants from New Zealand. Through our Universities and Government Departments, research is undertaken to free viruses from many plants, and these are now world recognised. Two that are of great importance are nandina and daphne and, in addition to this, many roses and ornamental cherries are currently being worked with.

Although some 12,000 miles away from its Northern Hemisphere customers in Europe, the regular supply by sea and air of ornamental liners has become an accepted part of the New Zealand nurserymen's business for a limited number of growers, but the continuity and expertise developed over the years has now seen a strong base and, in some cases, joint venturing between two nurseries in respective hemispheres.

Tissue Culture

This is one of the newest forms of propagation to enter New Zealand. Currently there are approximately five commercial tissue culture laboratories operating in New Zealand, but in association with this there are many small owner-operators who service other growers, especially in the orchid industry.

With its limited markets, especially with house plants, it is very easy to saturate these markets. New Zealand propagators have called upon the assistance of scientists from both Government and the Universities. This has assisted many laboratories into entering new fields that have not been touched on in other countries of the world, such as *Pinus radiata*, proteas, and bulb crops such as nerines and zantedeschias.

There is no doubt that tissue culture is here to stay as a means of propagation and the association of commercial laboratories with nurseries to carry out transfer operations, along with research for the future, has ensured a strong base for commercial tissue culture.

FRUITING PLANTS

There is little need to explain the role of kiwifruit within the New Zealand market. This plant, which was introduced many years ago from mainland China as the Chinese gooseberry, and now named kiwifruit (which is internationally accepted), has possibly been the driving force behind the recognition of horticulture. The skills that have been applied by the propagator to produce the traditional grafted plants, to rooted cutting, and more recently, tissue culture plants, have seen kiwifruit recognised as one of the leading plants within New Zealand for both local and export markets. Today it is a multi-million dollar earner both for fruit and plant exports, and large nurseries producing many hundreds of thousands of plants can be found spread across New Zealand.

The apple industry has always played a major role, and, as a result of new cultivars, rootstocks, breeding work, and selections introduced from overseas, the propagation of apple rootstock from tissue culture is now playing an important role in this continuing multi-million dollar earner for New Zealand.

The range of fruit crops that are planted throughout New Zealand varies from sub-tropicals such as feijoas, citrus, and avocado, to the recent introductions of persimmon and nashi (Asian pears).

The horticultural industry is wide, varied, and exciting in New Zealand. The ability of the propagator to develop skills, be prepared to change, and to accept the challenges of this industry will always ensure that those people coming on have as much to conquer as those that have passed through our industry. Truly our New Zealand propagator has a goodly heritage. Let us care for it, cherish and maintain it.

THE STORY OF SCABIOUS BUTTERFLY BLUE

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How it started

Although I was trained as a grower, I have never been very good at the growing of plants. I have always had a much greater interest in general management and, in particular, in selling and marketing. I have for a long time had the ambition to introduce a new plant and see it established as a brand leader. Although this had been attempted in the United Kingdom before, the job in my opinion had never been done effectively enough. When I analysed the problems, I found that they were two-fold—one was the high risk which would be related to the introduction of a plant, and the second was the finance which was required to initiate and sustain an effective promotional campaign. It seemed to me an ideal opportunity to co-operate with another major nursery in an attempt to spread the risks, improve the distribution capacity, and help reduce the financing of the promotional campaign.

In the spring of 1984 I approached a colleague of mine who is general manager of Fargro Plants to see if he shared the same interests in finding and marketing new plants. During the summer of 1984 we formed a joint company called—"Pride of Place Plants Ltd."—between Fargro Plants and Blakedown Nurseries Ltd.

The objective of this company is to find and market new, unusual, and unappreciated plants of garden merit.

Having formed the company we now needed a plant. Perhaps the other important ingredient to any new prospective venture is luck, and this is where "Lady Luck" took a hand. One of Fargro's growers, David Tristram, had lived for some time in the Irish Republic. During the course of his stay in Ireland he had been given a plant of a dwarf scabious. When he moved to England and became involved in nursery stock production he brought this and several other plants from his Irish garden and re-established them in England. It was about this time that David had started to propagate small quantities of this dwarf scabious. Luckily, none had been marketed at this stage.

We decided that this scabious could well be a suitable plant for our first joint marketing venture.

So what is so special about the scabious we now call 'Butterfly Blue'?

The cultivar is a sport of our indigenous scabious—*Scabiosa columbaria* (Figure 1). It is, of course, a herbaceous perennial. 'Butterfly Blue' differs from its parent in that it flowers con-

tinuously from April to November and, under mild conditions, may even flower in winter. It will grow on almost all types of soil, including those with a low pH. It is particularly successful on chalky soils. It is not fussy as far as aspect is concerned, succeeding well in full and partial sun and in light shade. It is compact and requires no staking; flower stems have a maximum height of 40 cms. Because of its dwarf and compact habit it is suitable for many garden uses, including flower beds and borders, patio tubs, and window boxes. An added attraction is that it is attractive to both butterflies and bees. It is also a useful cut flower, being long lasting when cut.

Figure 1. The appearance of *Scabiosa columbaria* 'Butterfly Blue' in flower.

Before we could market any plants we had to propagate and grow saleable plants within our nurseries. Propagation is a fairly simple matter from soft stem cuttings preferably with no flowers, which may be taken at any time during the growing season. Cuttings are inserted in 13 × 8 holed modular trays—the hole size being 4 cm; no hormone is given before insertion. The rooting medium used within the trays is 70% spagnum peat and 30% fine polystyrene granules. At certain times of the year we add a kilo of 9 month Osmocote and 1.2 kilos magnesium limestone per cubic metre. After insertion into trays the cuttings are rooted under a double-skinned polythene tunnel with hessian scrim and mist propagation. The scrim is a technique which you may have come across before. Used in conjunction with mist propagation it prevents high calcium deposits and leaching from the leaves; it also produces an excellent microclimate close to the plants. The technique was adapted from

work carried out by Dr. Keith Loach at the Glasshouse Crops Research Institute.

Rooting takes 10 to 14 days; bottom heat is only used at the end of the rooting season (September/October). Approximately 400 cuttings can be propagated from one mother plant each season. We are now beginning to use micropropagation as a means of reproducing the plant.

Growing

How the plants are potted-on depends at which time of the season they are rooted. Late summer rooted cuttings, say from August onwards, are potted into ½ litre pots and held in this size pot throughout the winter. Cuttings which are rooted in the spring and summer are directly potted into their final 1½ l pot. All the pots used are rigid black plastic. Compost is based on 75% peat and 25% grit, with Osmocote added. We require the majority of our saleable plants for the middle of April to coincide with increase in customer activity in garden centres. We continue a successional propagation and potting programme to ensure we have saleable plants from the middle of April until the middle of October.

Marketing

The first decision we had to make was how many plants we should grow for the initial launch. As we had never introduced a plant before there was no previous track to be guided by. We could only grow the number of plants which we had space for on our nurseries, and which we could afford to grow. On the other hand, we knew we must grow sufficient plants to cover the very high initial launch and promotional costs.

Above all, the number of plants which we would be able to produce would be controlled by the amount of propagation material we could obtain. We finally decided on the figure of 40,000. We then gave serious consideration to how we would sell 40,000 plants. From our previous experience we knew we would have to offer a basic promotional package, as follows:

20 × 30 in. 4-colour poster
6 × 8 in. bed head label
Large 4-colour individual plant label

In addition, we also decided to take full page colour advertisements in major gardening magazines by the side of which we listed the names of stockists of 'Butterfly Blue'.

We also decided to attempt to do something which had never been done in the hardy nursery stock industry in the United Kingdom—and that is, we would dictate the recommended retail price.

We eventually decided on a wholesale price of £1.27p, excluding V.A.T. This price was arrived at by taking the basic wholesale price of a herbaceous perennial which was 80p, deciding

that we should add a novelty premium, which we concluded should be 20p, and then adding on 27p to cover part of the promotional costs.

In the U.K. most garden centres "mark up" their plants by 100% and then add V.A.T. We felt that this would make our product too expensive and, therefore, recommended a retail price of £2.49p, inclusive of V.A.T., which equates to approximately 70% "mark up" on cost. I am pleased to say that garden centres have found this to be a satisfactory price point and "mark up". We did, of course, have two selling jobs to undertake. The first was to sell our plant to garden centres to stock. We accomplished this by producing Selling In Leaflets, explaining not only the attributes of the plants but the advertising and PR campaign which we were staging.

In addition, we attended several major trade shows and launched the plant at the International Garden Centre Association Conference and Exhibition in January, 1985. I think that even we were astounded by its initial success. We sold 10,000 plants in the first half-hour and the first crop of 40,000 within 3 weeks. During the course of 1985 we managed to increase our production from its original 40,000 to 70,000 and sold all the plants which we produced; in fact, there was a great shortage of material throughout the season.

Toward the end of 1985 we decided that we must keep the momentum going through the next season. Our promotional campaign of 1986 was a two-pronged attack. During 1985 we had discovered a pink sport of 'Butterfly Blue'. We decided to run a promotional campaign based on a competition to name this plant. Entry to the competition was only possible to those who purchased a 'Butterfly Blue'. We developed a prize structure which started at £5. and finished with a National Winner of £500. Again we produced an elaborate Selling In Leaflet, explaining the competition which was circulated to all reputable garden centres within the U.K.

I am pleased to say that the competition has been an outstanding success. Over 150 garden centres within the U.K. are actively involved in the promotion. To date we had had nearly 2,000 entries to the competition, with a choice of over 600 different names for our new pink scabious.

In addition to our competition, 1986 saw the opening of our first National Garden Festival at Stoke-on-Trent in Staffordshire—a great promotional opportunity. We decided to stage a large display of 'Butterfly Blue' at the Garden Festival. We picked a site just inside the entrance and planted the semi-circular beds up in April of 1986 with some 1500 plants. We also produced a leaflet which is available from all information kiosks at the National Garden Festival as well as giving details of the attributes of 'Butterfly Blue'; it also contains a list of all stockists in the U.K.

Has it been a success?

There has been a great deal of thought, effort, and money put into the marketing of scabious 'Butterfly Blue'. We have spent in excess of £20,000 ($30,000) on the promotional activity to date. This will have yielded sales by the end of this current season of some 270,000 plants—with a wholesale value not far short of £350,000, or in excess of half a million dollars.

It has also established Pride of Place Plants Ltd. as an organisation with credibility and an organisation capable of handling large scale plant introductions.

We feel confident that the annual market for 'Butterfly Blue' within the United Kingdom will be in the order of 100,000 to 150,000 plants per annum.

Plant breeders' rights

We took a decision in the early stages of our discussions not to put 'Butterfly Blue' in for plant protection rights in the United Kingdom; instead we registered the name Scabious Butterfly Blue as a trade mark.

We then adopted the policy of producing a large volume of plants in a short space of time on the assumption that we would have cornered the market. This policy has worked successfully.

VITRIFICATION OF PLANTS CULTURED *IN VITRO*

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The term "vitrification" describes morphological and physiological disorders of plants cultured *in vitro*. The descriptions of vitrified cultures given by various authors are very similar whatever the species involved. Stems are thickened and translucent, leaves thick, brittle, wrinkled, curled, and frequently very elongated, with no differentiated palisade tissue (Figure 1). There is a general hyperhydricity of the cells as well as a deficiency of chlorophyll, and usually the lignification of vessels and tracheids is defective (18). Such cultures lose all capacity for reproduction and may threaten the continuance of their clones. The problem is serious; most micropropagation laboratories face vitrification of their cultures and many tissue culturists have focused their efforts on practical means of avoiding vitrification (Table 1).

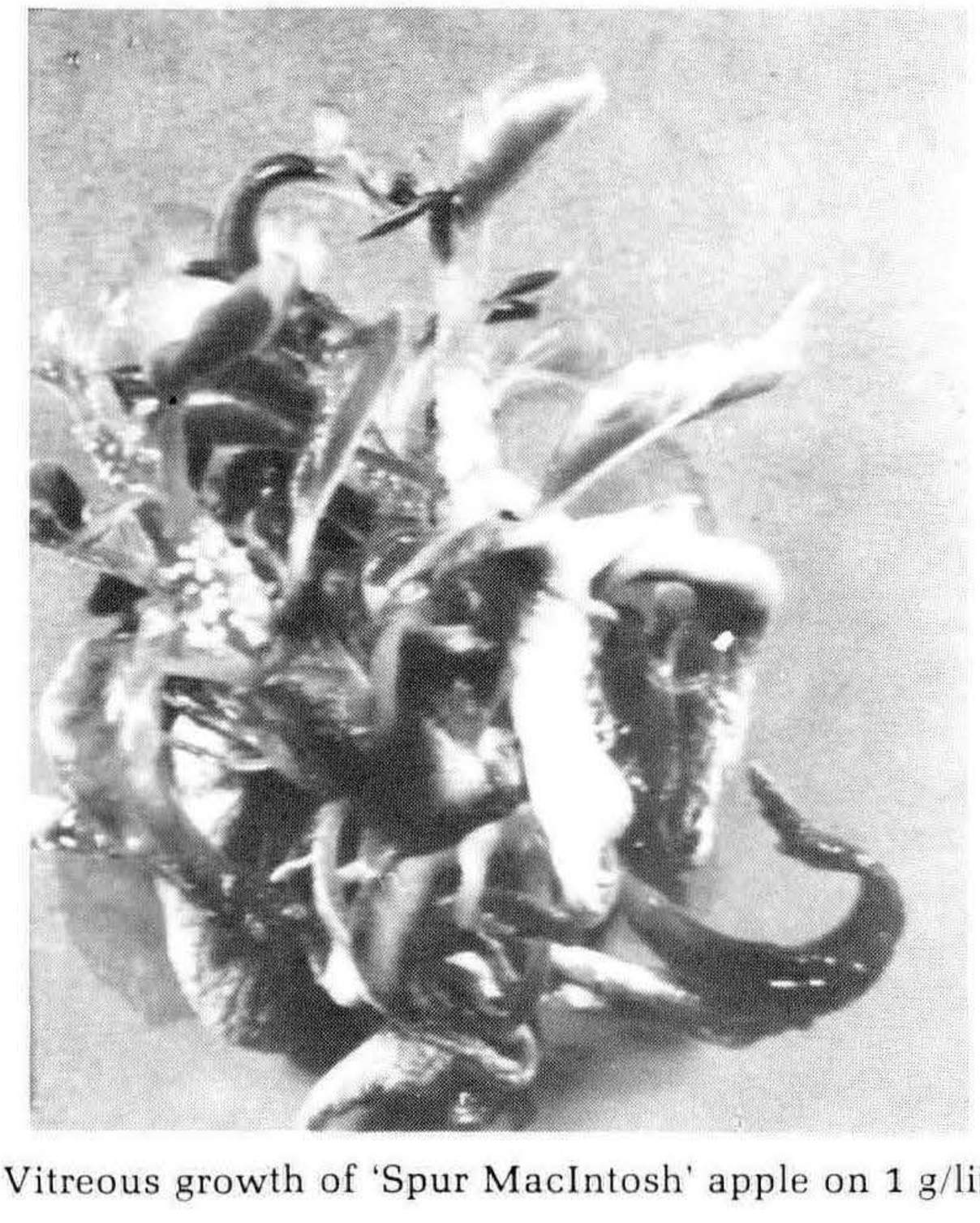

Figure 1. Vitreous growth of 'Spur MacIntosh' apple on 1 g/liter Gelrite.

Though numerous correlated factors are doubtless involved in this many-faceted phenomenon, the concentration and brand of agar, the level of benzyladenine (BA), and the content of ammonium ions are the main contributors of occurrence of vitrification.

Table 1. Percentage of vitrified shoots in four Italian micropropagation laboratories (Zanzi Vivai, Vitro Plant, Battistini, Vitro Coop). Mean over one year of cultures.

Percent of Vitrified Shoots			
Rootstocks		Species and Cultivars	
M 26	5 to 30	Peach	5 to 100
GF 677	5-to-30	Pear	30 to 40
GF 655/2	2 to 10	Apple	5 to 30
GF 43	2 to 30	Kiwifruit 'Tomuri'	20
CAB 6P	5 to 30	Kiwifruit 'Hayward'	30
CAB 11E	5 to 30	Chestnut	50
		Filbert	20

The concentration and brand of agar

The occurrence of vitrification is an agar-related problem. Agar should not be considered simply as a means of solidifying culture media. Both the concentration and brand of agar affect the chemical and physical characteristics of a culture medium (4). Moreover there are marked differences in nutrition composition among different agar brands (15), and striking variations in the solidity of gels among similar concentrations (4).

Tissue culture studies in recent years have demonstrated that agar concentrations have a strong influence on the growth and development of various explants (13, 16, 17, 19). Shoot growth and shoot proliferation of *Malus* 'Almey' and *Pyrus communis* 'Seckel' were significantly influenced by agar levels (14).

The incidence of vitrification could be lowered by raising the level of agar in the culture medium but, in so doing, shoot proliferation was reduced (5, 7). With globe artichoke, increasing the agar concentration from 0.6% to 1.1% eliminated shoot vitrification but halved shoot proliferation rate (Table 2). Debergh *et al.* (5) attributed this result to the matric potential, for which the agar would be responsible. Similar results were obtained with 'Gala' apple using Gelrite plus Sigma-agar as a gel (11).

Table 2. Influence of different concentrations of Difco Bacto-agar on percentage of vitrification and proliferation ratio. Partial data from Debergh *et al.* (5).

	Percent of Vitrified Shoots	Propagation Ratio
BM	60 to 90	3.75 a
BM + Agar, 0.6%	75 to 100	3.30 a
BM + Agar, 0.9%	20	1.90 c
BM + Agar, 1.1%	0	1.50 cd
BM + Agar, 1.5%	0	1.20 d
BM + Agar, 2.0%	0	1.00 d

Values followed by the same letter do not differ at $P \leq 0.05$ (Letter b is on data not reported).
BM = basic medium

As shown in Figure 2, the incidence of vitrification is lowered by increasing either Sigma-agar or Gelrite content. In this study no vitrification was produced by combinations of 1 to 1.5 g/liter Gelrite plus 2 to 4 g/liter agar.

Regarding agar brand, vitrification has sometimes been overcome by substituting one gelling agent for another. For example, apple cultivars become vitreous when Gelrite or Phytagar was used to solidify the proliferation medium (12), but not with Difco Bacto-agar. Gelrite is used commercially for *in vitro* propagation of some ornamental plants and of paradox walnut rootstock (6), but it induces vitrification with a lot of fruit plants (R. H. Zimmerman, personal communication). To prevent vitrification of their cultures, private laboratories test the quality of each stock of agar in a small number of jars before using it in large quantities.

The question is: how do the concentration and brand of agar influence the characteristics of the medium and thus vitrification?

First of all, with increased agar concentrations, the medium tends to be firmer, losing the characteristic fluid consistency typical of lower concentrations; the availability of water is diminished and the diffusion of macromolecules is restricted (13). Water is generally recognized as a key-point in vitrification; affected plants in fact have a greater diffusion of water into the cells. The reduced availability of water and of other components may lead to the inhibition of both vitrification and shoot proliferation.

Secondly, the chemical and physical properties of each agar are specific, so that one species may be influenced by such properties while others are not.

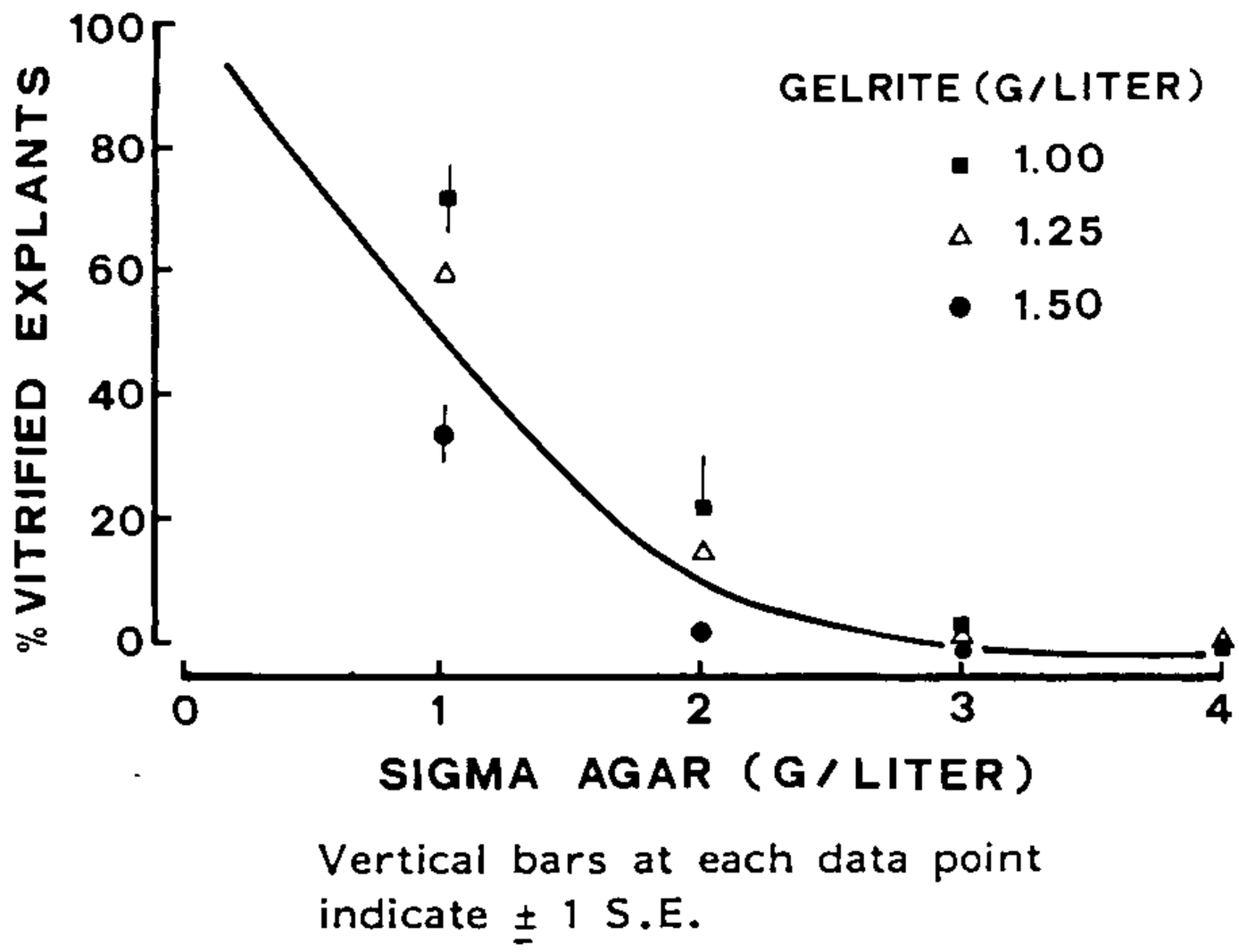

Figure 2. Effect of Sigma-agar concentration on percentage of vitrified explants at different concentrations of Gelrite. The curve indicates the trend of the phenomenon. Partial data from Pasqualetto *et al.* (11).

The level of BA

The basis of micropropagation is the stimulation of new shoots *in vitro* by treatment with an appropriate plant growth hormone. A cytokinin in the culture medium stimulates growth of axillary and/or adventitious buds.

Debergh (4) found that vitrification was influenced with BA levels at low agar concentrations. Bornman and Vogelmann (2) reported a high incidence of vitrescence in *Picea* sp. when gel media of low rigidity were used and, in particular, a highly significant negative correlation between the uptake and accumulation of 14C-labelled BA and the stiffness of the gel.

Vitrification of 'Gala' apple cultivar cultured on Murashige-Skoog medium (10) proved higher with 4.4 uM of BA than with 2.2 uM of BA (11). The vitreous condition in apple cultures can sometimes be overcome by transferring them from a medium containing BA to one with 2iP or no cytokinin at all (20). However, by reducing cytokinin levels in the medium, or changing type, we can limit or completely solve the problem of vitrification, but at the cost of lowering or halting shoot proliferation. On the other hand, it seems that the effect of BA on vitrification can be overcome by increasing gelling agent concentration, so that the effect occurs only at particular concentrations of the agar. Figure 3 shows clearly that at 0.5 to 1 g/liter agar the frequency of vitrification is higher than at 3 or 4 g/liter agar, but in both cases the concentration of BA makes little or no difference while at the other agar concentrations the BA level is influential.

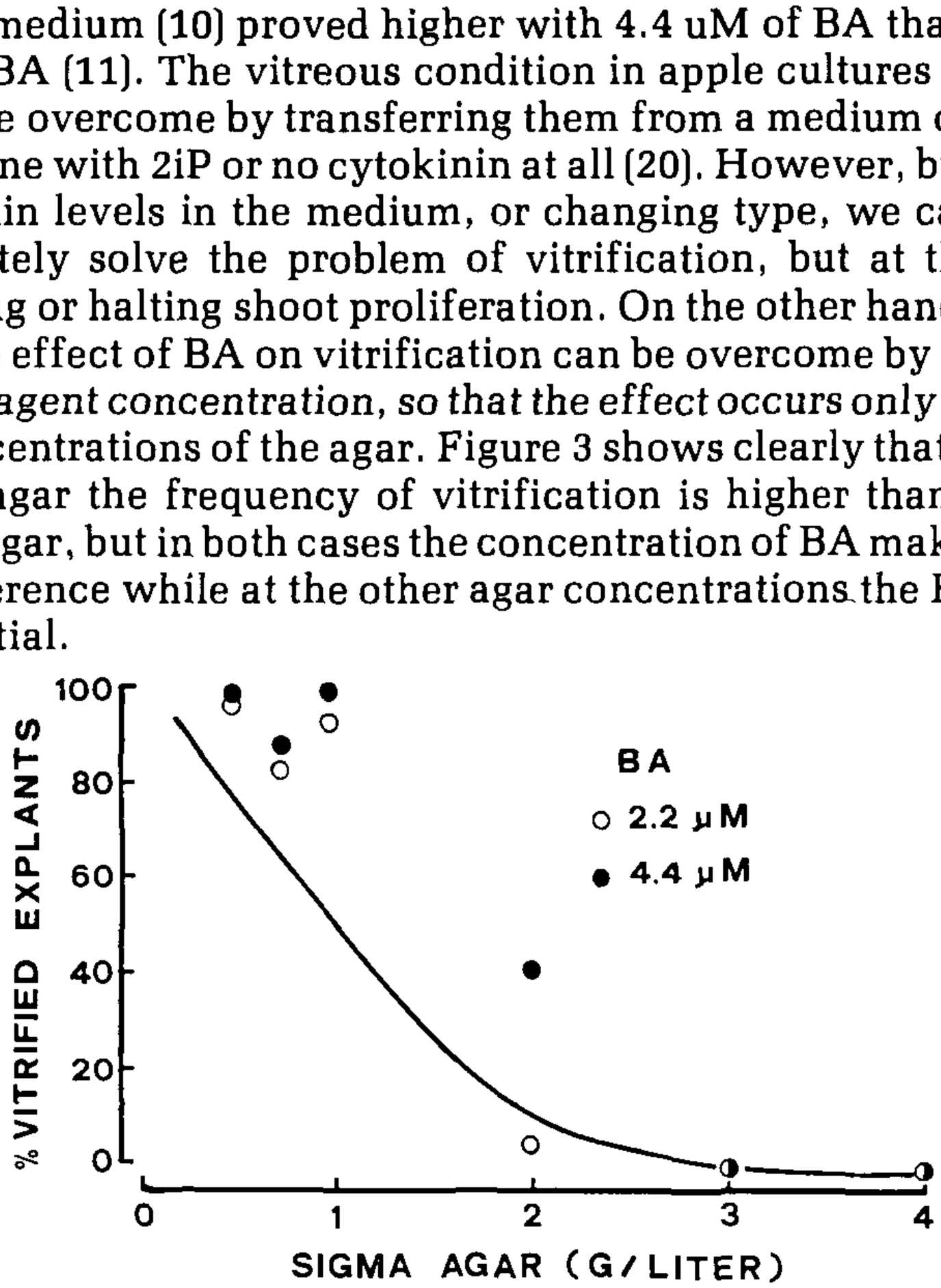

Figure 3. Effect of two levels of BA on percentage of vitrified explants. The curve indicates the trend of the phenomenon in relation to gelling agent concentration. Partial data from Pasqualetto *et al.* (11).

The content of ammonium ions

One salient feature of the syndrome is that most reported cases of vitrification have occurred using Murashige and Skoog's medium (10), which has a particularly high content of ammonium nitrate

(18). With *Salix babylonica*, vitrification of shoots was reduced by varying the quantity of nitrogen in the culture medium (3).

Vitrified shoots were produced in multiplication cultures of *Castanea sativa* when Murashige and Skoog medium was used in the subcultures, whereas normal shoots were obtained when Heller's macronutrient formula was used, with or without addition of 1 mM ammonium sulphate (18).

Two basic facts regarding the vitrification phenomenon are generally recognized: firstly, the reduction of lignin and cellulose content of tissues and, secondly, the enlargement of cells. One possible correlation between these two basic facts and ammonium ions has been suggested in the literature. Ammonium ions are assimilated faster than other nitrogen sources such as nitrates. Both ammonium ions and the lignin synthesis pathway need carbohydrates, so that a rapid uptake of the former may divert carbohydrates from the latter (1). Deficiency of lignin and cellulose, in fact, results from a decreased C/N ratio produced by an excess of N (9). Both deficiencies would tend to reduce wall pressure and so favour increased absorption of water with a consequent enlargement of the tissues.

CONCLUSIONS

Although growth room temperature and light sources cannot be ignored, agar, BA, and ammonium ions are more often described as factors able to eliminate the vitreous condition in cultures.

The availability of water in the culture jars seems to be a keypoint of the problem and agar, BA, and ammonium ions are in some way related to it. Increasing agar concentration reduces the availability of water and the translocation of macromolecules. Each brand of agar influences the chemical and physical characteristics of the medium in a specific way and consequently the water status in the jar. Cytokinins can cause an increase in the size of leaf tissues by a process involving only cell enlargement (8), while rapid ammonium ion uptake brings about a drop in the C/N ratio, leading to a deficiency of lignin and cellulose with a consequent absorption of water into the cells.

On the other hand, vitrification can occur in one laboratory and not in another even when both use the same techniques of *in vitro* culture and even the same plants (4).

A solution to this problem, and especially one able to maximize shoot proliferation and minimize vitrification, will require simultaneous attention to a number of different factors, including those considered above.

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STATUS OF CROP IMPROVEMENT THROUGH TISSUE CULTURE

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Plant propagation *in vitro* has been a well established technology for over two decades and has been in commercial use for a significant part of that time.

The commercial use of plant tissue culture today primarily involves the micropropagation of ornamental species and the production of early generations of disease-free transplants. Although the number of commercial laboratories in the United States and Canada have been estimated to be as high as 250, there are probably not more than five or ten which produce more than five million plantlets per year.

The commercial micropropagation of agronomic crops is not at the same volume level as ornamentals but is growing in the overall market. Examples include sugar cane, date palm, oil palm, several types of fruit trees, jojoba, and potato.

While micropropagation has been the principal form of tissue culture utilized at the commercial level, other aspects of tissue culture technology and other advanced biotechnological techniques will be commercialized in the next several years. All of these can be expected to have an enormous impact on crop improvement. How this will be achieved can be best illustrated by: 1) briefly reviewing some of the technologies now being commercialized in agriculture, 2) providing examples of commercial use today and requirements for future improvements, and 3) providing a basis for their market potential.

TECHNOLOGY REVIEW

At first glance, recombinant DNA technology may seem far afield from a discussion on plant tissue culture. Yet, given what is known about this particular form of genetic engineering, the manipulation and transfer of genes in plant cells using recombinant technologies requires plant and cell culture techniques to translate a sophisticated technical achievement into a commercially meaningful product.

There are several areas where commercialization of this technology might be realized within the next five to ten years. Improving the photosynthetic efficiency of crops using genetic engineering could generate an added value of $8 billion through increased

[1] President and Chief Executive Officer

yields. This is considered by many to be a very difficult technological target. Another aggressive target is direct nitrogen fixation in non-leguminous crops which is valued at $1.3 billion. The shortest term target which is both technologically achievable and has high commercial potential is herbicide resistance. Herbicide resistance has been introduced into several plant species by rDNA. Herbicide resistant crops, essential to minimum-till systems, could be worth $4 billion per year.

Given that the commercial opportunities emanating from recombinant technologies are a bit long term, what contributions can be expected from plant cell biology? Cell culture, while not as glamorous as the recombinant technologies, is critical to the commercialization process. It represents an enabling technology for the conversion of genetically manipulated plant cells into whole plants. Plant cell culture systems also provide a means for manipulating genes through various screening and selection processes. Two of the best known selection methods using cell culture are somaclonal variation and directed mutation. In fact, cell culture currently offers a faster means to achieve some of the goals set by molecular geneticists because the methodologies are better defined.

Cell selection technology takes advantage of the variation which naturally occurs in some plants regenerated from tissue culture. The genetic variation may already exist, but may not be seen until after the plant has been through culture, or the culture may force the change even though that was not the intention. One plant biotechnology firm, DNA Plant Technology, is using somaclonal variation to improve soluble solids in tomatoes. The economic benefit to the tomato processing industry is measured in millions of dollars saved at the processing plant.

Directed mutation methods take a lot of the guesswork out of somatic cell selection. With these techniques, cells are subjected to a mutagen, then put through a specific assay, such as high salt content. The survivors are selected and allowed to develop into plants. They will go through another round of lab selection and finally be field tested. Scientists at Plant Genetics, Inc. have selected a line of alfalfa cells using the mutagen technique. This line of alfalfa cells has survived a salt water assay at levels approaching 75 percent sea water. The survivors can be combined with alfalfa plants possessing other desirable traits to develop new cultivars. The economic consequences of developing salt and drought tolerant agronomic crops are enormous, being measured in the billions of dollars.

CASE STUDIES

Once a cell line has been selected, regardless of the technology employed, it is necessary to convert the cells to whole plants. Tissue or cell culture propagation plays an important role in this process.

Two examples of tissue and cell culture application serve to illustrate how these technologies are being used to commercialize agronomic crops. The first case study describes the use of micropropagation in potato "seed" tuber production. The second case study illustrates the use of cell culture and somatic embryogenesis in developing new synthetic seeds.

Micropropagation. Plant Genetics, Inc. specializes in plant cell and tissue culture technologies. The company has applied these technologies in commercializing its NU-SPUD™ brand potato line. Using micropropagation, a disease-tested high quality "seed" potato tuber is produced and sold to those growers who are at the very beginning of the potato seed increase cycle. Potatoes are generally grown from actual pieces of potato and increased over four to six years before being planted in a commercial field. If a grower starts off with diseased seed in the first year, millions of dollars can be lost.

The first state in the production of NU-SPUD brand potato products involves meristem culture, a disease-testing quality assurance protocol, followed by large scale micropropagation. The second state of production involves the transfer of disease-tested transplants to production greenhouses where whole tubers are produced and harvested. Commercial grade ranges from 0.25 to 1.5 ounces. NU-SPUD products have been sold in the major potato growing areas of the United States and Canada and have been shipped to China, Thailand, Taiwan, and Yugoslavia. This segment of the "seed" potato market represents a $350 million opportunity worldwide, with the United States and Canada representing only a small portion of this market. The NU-SPUD brand potato story offers an excellent example of how plant tissue culture is being applied today for the commercial production of the world's fourth major food crop.

Somatic Embryogenesis. A very key advance that will be required in the commercialization process of agronomic crops centers around that element of plant/cell culture called somatic embryogenesis. Somatic embryogenesis is one of the two technologies critical to the development of what is now called synthetic seed, and provides the basis for the second case study.

The process of making somatic embryos is exacting. Cuttings are taken from plant tissue and placed on a defined cell culture medium. Callus, or masses of disorganized single cells, will form from the cuttings. By changing the medium composition the cells are triggered to form embryos, not unlike the ones found in true seed. These embryos can be increased either on solid medium or in liquid culture medium. To make this process commercially viable, it is necessary to develop a large-scale liquid culture system. Once accomplished, it is estimated, for example, that one quart of liquid culture medium will produce enough celery embryos to plant about

25 to 30 acres. Commercial efforts are now ongoing to test plant cell cultures in specially designed bioreactors in which variables such as temperature, gases, and pH can be regulated.

Plant Genetics, Inc. has developed somatic embryo systems in cotton, alfalfa, lettuce, and celery. To make this system workable in the field and greenhouse, a protective coating or capsule is required. To address this issue the Company has developed a delivery system trademarked GEL-COAT™, a hydrated polymer gel surrounded by a membrane. Somatic embryos encapsulated in GEL-COAT are referred to as synthetic seed. In the case of some high value crops such as celery it may be possible to sell the synthetic seed directly to the grower or transplanter. With crops such as alfalfa, where the seed cost is low, this system can be integrated with a more traditional breeding program to develop and produce novel cultivars which will then be sold as seed.

AUTOMATION AND COMMERCIALIZATION

The ultimate commercial success of advanced cell and tissue culture technologies will be judged by the marketplace. Critical to this success is the implementation of large scale, low-cost automated production systems. As evidenced by the NU-SPUD illustration, the micropropagation industry is not necessarily limited to ornamental products. It has potential applications throughout the entire range of propagatable crops, perhaps even entering markets where transplants are traditionally produced from seed. If this picture is to materialize, it will be on the basis of being able to offer a quality, unique, or differentiated product as a transplant at a cost equal to or less than is currently charged. Since high volume vegetative propagules are produced for less than one cent apiece, and seed of most crops costs less than 0.01 cent, the challenge is great. The central issue facing commercially oriented plant tissue culture researchers today is how costs can be reduced to a fraction of what they are, while maintaining the quality of the end product.

Aside from the technical advantages achievable through plant tissue and cell culture, the major factor influencing the end users' decision to commercially propagate a plant through tissue culture is the performance or economics of alternate propagation systems operating in the marketplace. While technical factors may drive the need to culture a plant *in vitro,* the economic factor determines the feasibility of commercialization.

A major stumbling block to the large scale automation of tissue culture propagation has been the fact that detailed economic analyses of large volume tissue culture operations have not, until recently, been available to biologists and engineers with the research skills to attach key cost-intensive steps of a production process. A detailed analysis of this subject has been presented in other recent publications (1, 2).

Factors limiting unit productivity are inherent in processes dependent on manual operations. In discussions with major tissue culture production operations in the United States, a ceiling to productivity per operator-day appears to occur at about 5,000 operations, or transfer, per day. This appears to be a fair estimate of the maximum daily efficiency achievable using manual labor. This peak rate is rarely sustained over time; in general, good productivity is considered to be in the range of 50 percent of this number, or 2,500 transfers per operator per day. Average productivity over various tasks is influenced by culture vessel structure. For example, lower numbers per operator-day are encountered in test tube systems versus petri dish culture vessels (2).

Marketing considerations are a key element to the successful commercialization of automated tissue culture systems. The relationships between supply, demand, development costs, production costs, operating costs, and amortization must be carefully analyzed. It is particularly clear that the anticipated markets must possess the requisite volume and profit potential to bear the development costs of an automated system. Since first generation systems may be quickly superceded by technological advances, cost recovery for machines must be planned for rather short periods of time, say 24 months. Markets with the appropriate potential are now being identified and automation work is progressing.

One alternative to micropropagation which sidesteps many of the most difficult technical issues of automation is the encapsulation of somatic embryos for delivery as a direct analog to seeds. Somatic embryos can now be produced in a wide array of species and hold the promise of producing propagules at a fraction of the cost of other systems. The encapsulation of somatic embryos in gel-like substances has good automation potential. While embryogenesis and encapsulation technologies are still in a research phase, automation of synthetic seed production is conceptually more straightforward than any other micropropagation system. The production of many thousands of somatic embryos from only a few grams of cultured cells offers substantial cost advantages and makes it the prime candidate for production of large numbers at less than 0.01 cent per unit. The mechanical planting of encapsulated units, such as synthetic seeds, appears readily achievable using currently available greenhouse and field seed planters. The planting of synthetic seeds is not significantly different from the planting of a similar-sized zygotic seed. To be mechanically acceptable, synthetic seeds must flow through equipment easily and be fairly uniform in size and shape.

What appears to be emerging in the industry is the convergence of the skills in biology, engineering, and marketing necessary to drive the innovation process in this arena. Several firms are either taking their first real steps toward automation *in vitro* produc-

tion or have become fully committed. The near future promises many interesting possibilities.

CONCLUSION

On reviewing the new technologies and their potential economic impact it becomes evident that any economic assessment of the importance of biotechnology to agriculture is still very speculative. It is difficult to place a value on products which do not yet exist. Those that are in the marketplace or on the threshold of commercialization offer exciting prospects. The clear objective is that biotechnology will be applied in ways which will reduce costs to farmers, increase production efficiency, broaden genetic diversity, and enhance biological and economic stability.

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CROP MODELING AND PRODUCTION COSTS

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A crop model is a mathematical representation of how a crop grows and develops. Although not much modeling has been done on horticultural crops, there are a number of agronomic modeling projects. Over the last few years many of these have developed to the stage where it is now possible to develop management tools from the results.

Only recently have research dollars been allocated for modeling horticultural crops. This is probably due to the realization that benefits are possible for the horticulture industry. The greenhouse industry has, for example, discovered that a crucial step in the area of automated environmental control is to be able to provide the control computer with some representation of how the plant responds to modifications in the environment. Those interested in production can benefit by having a lot of crop-specific information placed into a package which mimics the crop's response to changes in cultural practices. With such a model it is possible to develop cultivars (through breeding programs) which are

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more efficient in ways only apparent through a modeling analysis.

This paper gives a brief overview of crop modeling and then focuses on two ways in which crop models can be used to optimize horticultural production. The first is in selecting for plants which will be, in some way, less expensive to produce. The second involves reducing costs while increasing productivity through automated environmental control.

WHAT IS A MATHEMATICAL MODEL

A model is an abstract representation of something real. A mathematical model is one consisting entirely of mathematical equations. For example, the formula:

$$P = P_o(1 + r)^n \quad (1)$$

is a mathematical model of the value (P) of some invested amount (P_o) of money at interest rate r per period of time for n such periods. Similarly, plant growth can be described with variables (such as P, P_o and n above) by selecting a measurable characteristic of the plant (such as height or weight) and developing formulae which simulate (predict) the values of these variables over time in response to prevailing environmental factors (such as light intensity, air temperature, and carbon dioxide concentration).

It is generally not possible to describe the growth and development of a crop with one equation if it is to represent the process of plant growth and its response to many environmental factors and cultural practices. Plant growth can be conceptualized as consisting of a number of processes such as photosynthesis, respiration, distribution of accumulated photosynthates; leaf expansion, leaf and flower initiation, etc. Each of these processes is affected to a different degree by the environment and, in turn, affects the growth process as a whole in different ways. Thus a number of equations are required for each process, with an additional set of equations being needed to tie them all together into one model for the crop.

The science of developing these involves five stages of research and development: 1) identification of the problem and scope, 2) analysis of processes involved in crop growth and development, 3) constructing mathematical relationships which validly and quantitatively represent these processes, 4) combining these components (called submodels) into a dynamic system which models the plant, and 5) validating that the devised model actually represents the plant.

APPLICATION OF CROP MODELS

Using Modeling in Breeding. Mathematical models can be used in breeding to develop selection criteria. Selection can be based

on directly observable characteristics such as: plant height, internode length, and flower color, or traits which, although not directly observable, are easily assessed. Examples of the latter would be drought tolerance, pathogen resistance, herbicide resistance, etc. Dealing with these types of breeding problems is fairly straightforward.

Models can provide a tool in cases where desired traits are not directly observable. The basic approach is to develop a model to represent how the plant grows and develops using parameters which quantify the desired traits. For example, a cultivar of a foliage plant with a high light utilization efficiency, a high maximum rate of photosynthesis, and a low temperature at which this maximum occurs, would have more resources for growth. Each of these characteristics could be a parameter of the model.

In this case data would be collected to develop a model involving all these parameters. Ideally this would entail development of a three dimensional model (photosynthetic rate versus light and temperature). Photosynthesis rates would be measured at a wide range of light and temperature values. The model is then fit to this data by using a statistical regression program to determine the parameter values which minimize the difference between the model and the data. These values are then used in breeding in the same way as measures of observable traits.

An illustration of this is part of a study being carried out by Dr. Aage Andersen at the Royal Veterinary and Agricultural University in Copenhagen, Denmark. A large number of different clones of *Ficus benjamina*, obtained from a variety of sources, are being grown. The objective of the study is to find which clone would minimize production costs while maintaining a high market value. To accomplish this it is desirable to select the clones with the maximum net photosynthetic rate at a relatively low temperature while the rate at this temperature is high. This would assure that the members of the resulting population would be capable of high photosynthetic rates at conditions which are inexpensive to maintain in Denmark's climate. Figure 1 illustrates the response of the photosynthetic rate (mg CO_2 per second per square meter of leaf area) to temperature at a fixed light level. A quadratic model can be used to describe this data:

$$PSYN = B - C\,(TEMP\text{-}A)^2 \quad (2)$$

where B is the maximum value, A is the temperature where this maximum occurs, and C is a scale factor which determines how "flat" the peak is. TEMP is temperature (°C) while PSYN is net photosynthetic rate. The smaller the value of C the "flatter" the peak. Fitting the above equation to the data from each clone resulted in the five curves in Figure 2. The corresponding parameter values (Table 1) provide the numbers which would then be used in the selec-

tion process. In considering the maximum rate, clone M is a clear favorite. However, it is not significantly better than any of the others when looking only at the temperature at which this maximum occurs. In fact, Dr. Andersen has found that this parameter seems to be the same for all *Ficus benjamina* plants he has measured. Yet, it may be possible, by always selecting clones with lower values for A, that a significant difference might show itself after a number of generations.

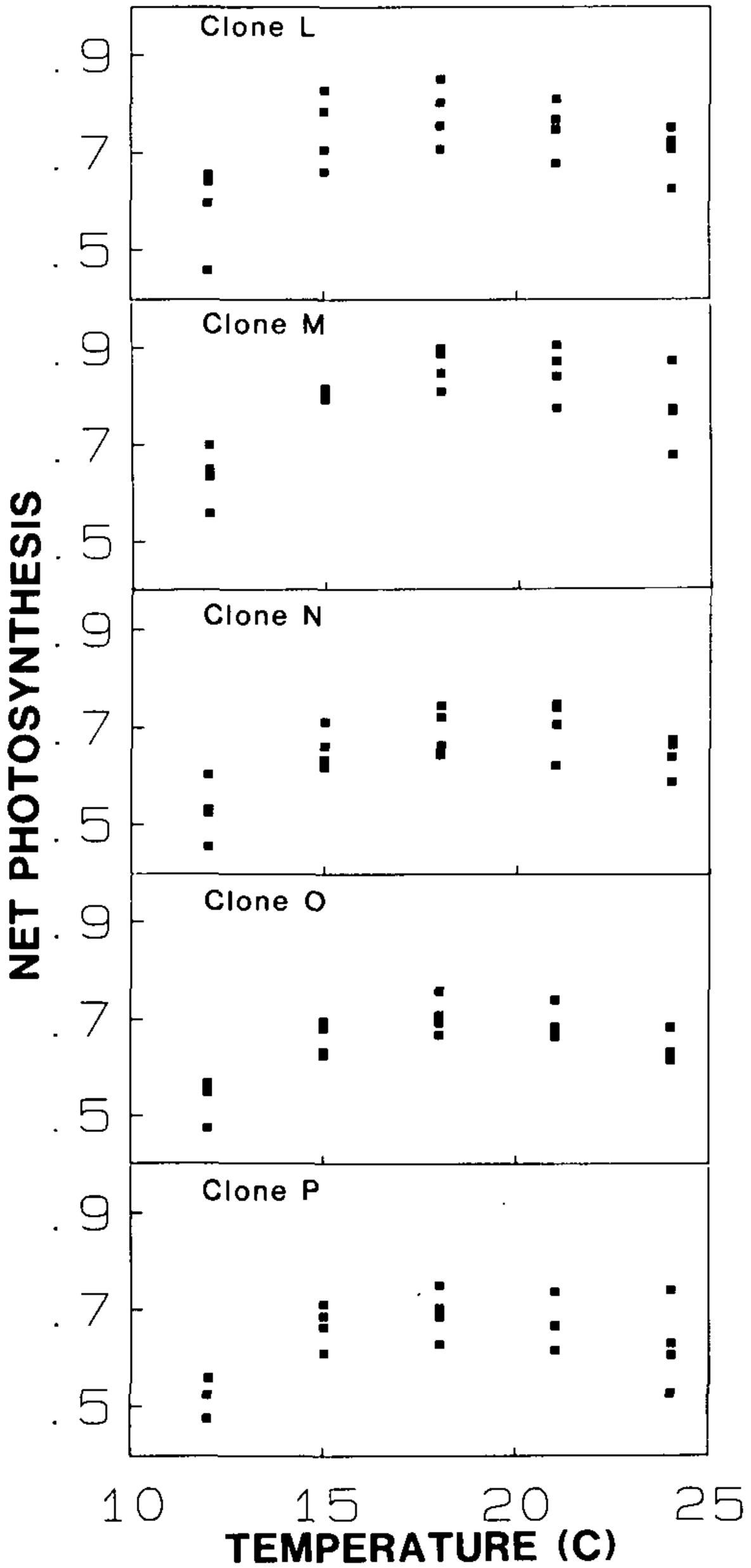

Figure 1. Net photosynthesis (mg CO_2 s^{-1} m^{-2}) data for five clones of *Ficus benjamina*.

Using C as a selection criterion might also be useful. The smaller this number, the flatter the curve. A flatter curve would indicate that the plant would operate near the maximum rate over a wider range of temperatures.

Table 1. Parameter values of the best least squares fit of equation (2) to the photosynthesis data of each clone. The units for the parameters are: A, °C; B, mg CO_2 s^{-1} m^{-2}leaf area; and C, mg CO_2 s^{-1} m^{-2} $°C^{-2}$.

	Parameter		
Clone	Temperature of Photosynthetic Maximum (A)	Maximum Net Photosynthetic Rate (B)	C
L	19.0	0.784	0.00376
M	19.2	0.869	0.00444
N	19.4	0.711	0.00325
O	19.2	0.711	0.00324
P	19.0	0.699	0.00330

Using Models in the Optimization of Production Costs. Physiologically based crop models can, in principle, be developed into management tools. For example, crop growth models based on environmental variables including water availability and nutrient dynamics can usually be converted into irrigation scheduling tools. Furthermore, since models provide a way of representing the plant to electronic equipment controlling the environment, it may be possible to convert this irrigation scheduling tool so that it can be linked directly to electronic equipment to automatically control when and how much water is applied.

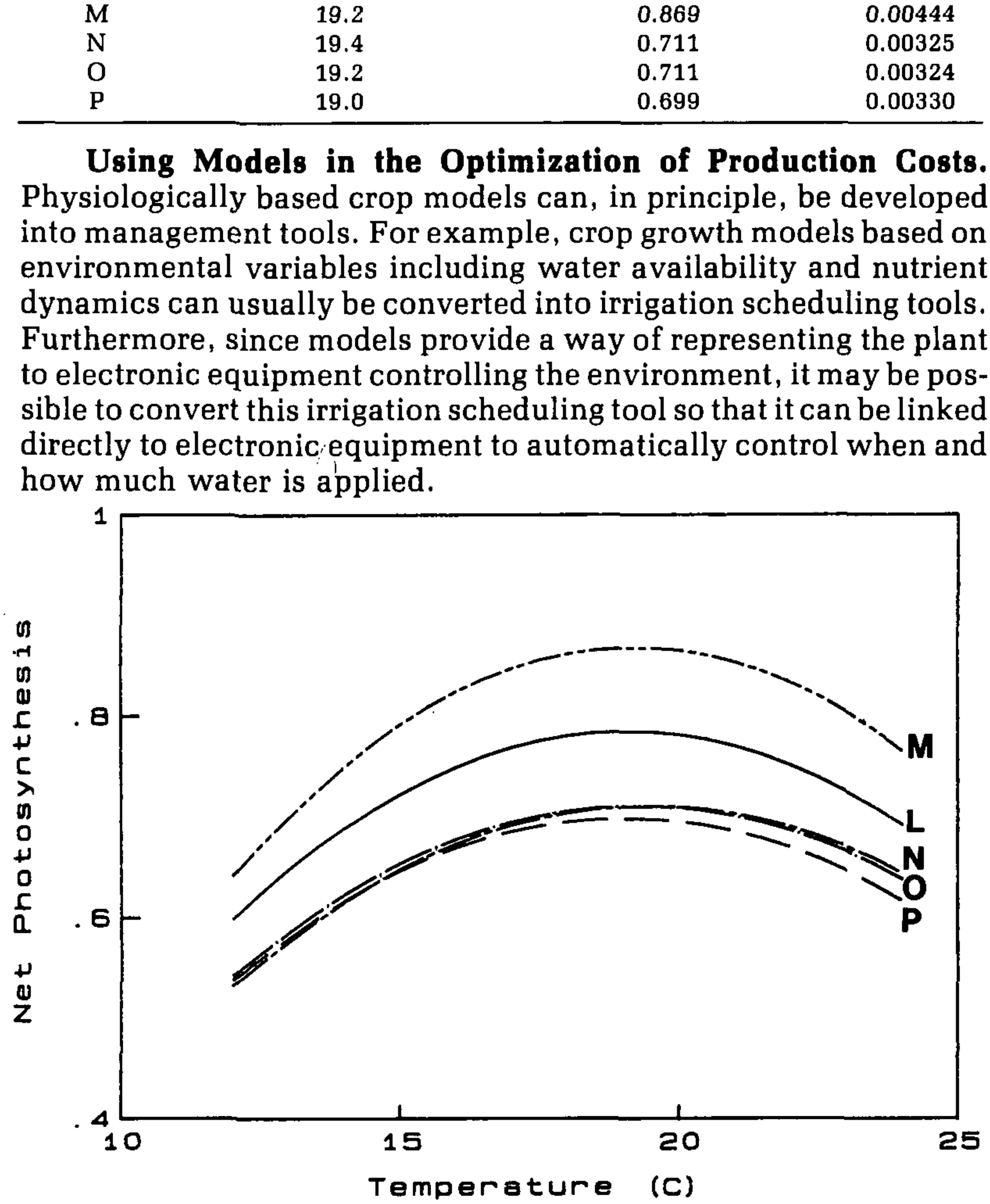

Figure 2. Polynomial least square fits of equation (2) to the data in Figure 1.

Many modeling projects which have succeeded in developing models for particular crops, are now converting these into management tools. For example, there are a number of modeling projects involving cotton. Some of these projects have been active for more than a decade. In that time, complex, large scale, physiologically based models for the growth of cotton have been developed. These respond to many environmental parameters such as temperature, light, fertilizer level, water, and pests, and can be used to forecast how cotton grows under field conditions.

One such project, SIRITAC, is a cotton model being developed in Australia. The model has evolved into a management tool operated by a cooperative of cotton growers (1). The model is capable of accepting and using data of the current growing season to forecast how, if future weather conditions are characterized by historical data, the crop will develop. Various possible management strategies can then be tested to see which yield will maximize profit. Another cotton model, GOSSYM, developed by USDA scientists, is currently being incorporated in a system of computer programs designed to accept information from the user and make management suggestions such as fertilizer and watering recommendations (2).

At the present time I am developing models which can find application in the ornamental floriculture industry. One of these is a model which simulates the growth and development of potted Easter lily. This crop is a particularly energy intensive crop since it is grown in warm greenhouses in the winter months. This means that a lot of energy is exerted to get this crop to grow and flower in time for Easter. If, for some reason, the crop falls behind schedule, the grower catches up by raising the temperature to speed up the plant processes. It would be useful to have a model which allows the grower to test various strategies for making his crop catch up. He might, for example, find that he will inevitably have to supply additional heat but that, rather than having to do it in February, he can delay this until March when the differential between the inside and outside temperatures is smaller. Consequently less energy is required. At this point it is unknown whether this would work.

Linking models to electronic environmental control equipment is likely to provide a very powerful tool for growers. Many growers are currently installing (or have installed) computers to control the environment in their greenhouses. At present this equipment is used like a thermostat since an operator still has to set the levels which he feels are best for the crop. The main benefit, at this time, is that he has more control over more variables such as temperature, relative humidity, CO_2 concentration, and light levels. In all cases, however, no system is, as yet, able to automatically select the levels which are optimal for crop growth. A mathematical crop model representing how the plant responds to its

environment, can theoretically be used to either automatically set optimal conditions or to inform the operator of the optimal levels.

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THE USE OF COMPUTERS IN NURSERY CROP PRODUCTION

LORENCE R. OKI

Oki Nursery Company
P.O. Box 7118
Sacramento, California 95826

Computers at Oki Nursery are not a new sight. We obtained an IBM 403 Card Sorting System about 1960. Programming the machine required actual rewiring of a program board. Later, we graduated to an IBM System 3 and in 1980 to our current computer, an IBM System 38. With this computer, we have linked our Portland branch to our main office in Sacramento. There are more than 12 terminals distributed through the main office in Sacramento and between 20 to 30 people a day use the computer to utilize its processing capabilities or to access information which is held in its memory. Lately we have been networking personal computers to the System 38 to increase our capabilities. Our major applications are order entry, order picking, inventory, truck dispatching, accounting, payroll, credit, and accounts receivable, accounts payable, crop planning, and a variety of management reports.

Now, let me tell you about my personal experiences with a computer because I am not an expert with it. I want to assure you that it does not take a genius to figure out how to use them—because I am not one. A computer is just a machine—a tool. Just like you use a forklift to help move material or a soil machine to fill flats, you can use a computer to help with your business. But as with all tools, you can utilize a computer to its maximum potential or you can waste it if you are afraid to use it or do not learn to use it properly. You cannot be afraid of it and you have to make a commitment to yourself that it will work.

If you've decided that a computer can be part of your business, the next decision to make is not what kind of computer to buy, but what do you want to do. Do you want to use it to do accounting? Do

environment, can theoretically be used to either automatically set optimal conditions or to inform the operator of the optimal levels.

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If you've decided that a computer can be part of your business, the next decision to make is not what kind of computer to buy, but what do you want to do. Do you want to use it to do accounting? Do

you want to use it to help with your production? After you answer these questions, then you will need help. Tell the person who is helping you what you want to do—be as specific as possible. He can then help you with the software that is available. When you have a list of software to use—then you decide on the hardware—the computer to run the software and any peripherals you'll need (probably at least a printer).

The one thing that all businesses have in common is accounting. And since there are so many businesses, it follows that there is a lot of software to help with accounting—general ledger, accounts payable, accounts receivable, payroll, inventory. A nursery is a business, so if you've decided that this is where you want to use a computer, there will be a large selection of "canned" or ready-to-use programs available. A nursery can also use crop scheduling, space allocation programs, and other production aids. But since nurseries constitute a relatively small percentage of all business there are few "canned" programs available that are applicable. But the uses for a computer in nursery production are still limitless. You can have seed sowing schedules, purchasing, transplanting schedules, labor requirements, space requirements, and on and on.

I started using a computer for production about two years ago and I want to share with you some of the uses that I have developed and to tell you a little about how I came up with them. The system that I am using is an IBM-PC, using Lotus 1-2-3. One of the reasons I decided on this system is simply because I do not know how to use the mainframe computer at our office and Lotus is easy to use on the P.C. I had no experience with this system but I did manage to begin writing programs the first day I started using it. The reason it was so easy is because of the tutorials that are included with both the machine and the software. There are classes that are available, too, should you decide to take advantage of them.

Lotus is what is called a spreadsheet program. A spreadsheet can be thought of as a ruled paper with each entry you make in a "cell". Each cell has an "address". Columns are labeled at the top alphabetically, rows are numbered at the right. The upper left-most cell is "A1".

Math operations are straightforward. Formulas are pretty much written as a regular math formula but they can get complicated. I will be giving you examples of simple formulas and show you more advanced ones. My purpose is not to teach you how to program but to show you what spreadsheets are capable of doing.

Let us start with a simple spreadsheet so that you can become familiar with terms and some procedures. Let us say that the cells in column "A" are the number of flats of a certain plant you want to produce. The next cell in column "B" is the number of labels you will need. We will write the formula and the results will appear in

column "C". The formulas should be: +A6*B6 (Figure 1). Since the number of labels per flats should be constant, let's say 15, you can also write: +A6*15.

C6: +A6*B6

	A	B	C	D
1				
2		QTY LABELS	TOTAL	
3	QTY FLATS	NEEDED	QTY LABELS	
4	PRODUCED	PER FLAT	REQUIRED	
5	----------	----------	----------	
6	100	15	1500	
7				
8				
9				
10				
11				
12				

Figure 1. Portion of a simple spreadsheet showing total quantity of labels required.

This is a specific example (Figure 2). At our company, cp's (or cell packs) require 15 labels per flat, pp's (or pot packs) (or jumbo packs) need 6 per flat, p4's (or 4 inch pots) need 16 per flat. The information that needs to be provided are the amounts of each size that we expect to produce. The formula for the "quantity of labels required" would be the number of cp's times 15 plus the number of pp's times 6 plus the number of p4's times 16. The answer will be the amount of labels that you will need. The formula will look something like:

+B6*15+C6*6+D6*16

E6: [W12] +B6*15+C6*6+D6*16

	A	B	C	D	E
1					
2		# FLATS TO PRODUCE			TOTAL
3		----------			QTY LABELS
4	VARIETY	CP	PP	P4	REQUIRED
5	----------	----------	----------	----------	----------
6	AGERATUM	100	50	75	3000
7					
8					
9					
10					
11					
12					

Figure 2. Specific example of a spreadsheet portion showing total labels required *for ageratum.*

After we take the inventory out then we will get the quantity that we will actually need to order (Figure 3). The formula will be:

+E6–F6

E6: [W12] +B6*13+C6*6+D6*16

	A	B	C	D	E	F	G
1							
2		# FLATS TO PRODUCE			TOTAL		
3		---	---	---	QTY LABELS	INVENTORY	QTY LABELS
4	VARIETY	CP	PP	P4	REQUIRED	ON HAND	TO ORDER
5	---	---	---	---	---	---	---
6	AGERATUM	100	50	75	3000	750	2250
7							
8							
9							
10							
11							
12							

Figure 3. Spreadsheet showing quantity of labels that need to be ordered.

Now, let us say you produce 250 cultivars of plants. You can put together a label order in the amount of time it takes to enter the numbers.

It used to take me about 2 weeks to produce our seed order by hand. The process included doing a sales analysis of the previous season, developing a projection of the next season and then finally producing the seed order. Using sales information from our mainframe computer, it only takes about 2 hours to develop the projections for our annuals product line of the spring. After I enter the projection into the computer along with our seed inventory, a seed order is produced. Now it is very easy to produce an order well within a day. Of course, there are always changes in projections after everyone in sales and production finishes making their analysis but changes are easy to make.

The spreadsheet can also help produce production schedules. Here is an example of a portion of a sowing schedule. This program may not be the most efficient. There is probably an easier way to do it—but it works this way. Using *Ageratum* 'Blue Blazer' as an example, the way the spreadsheet works is like this (Figures 4–6):

The dates on the right are the sowing dates by week. On April 7, the program calculates the date (June 9) that would be 9 weeks ("No. wks sow to sale") later and looks for a quantity. If there is no amount to be produced on the date that has been calculated, then it simply puts a zero—nothing to sow at this date. On April 14, it does the same thing—9 weeks from April 14, on June 16, we would like to have 25 flats ready. A calculation is made to determine the number of trays (11) to sow and is indicated to sow on April 14.

```
C9: (F0) [W7] 25

          A       B    C       D       E       F       G       H       I       J
1
2                                SOWING SCHEDULE FOR 1986 (CP) SUMMER CROP
3
4                                      QTY TO SELL 1986
5
6
7       VARIETY    I02-Jun 09-Jun 16-Jun 23-Jun 30-Jun 07-Jul 14-Jul 21-Jul
8    --------------I-----------------------------------------------------------
9    Ageratum BlueI     25              25              20              20
10
11
12
```

Figure 4. Spreadsheet showing sowing schedule for 1986 summer crop of *Ageratum* 'Blue Blazer'.

```
Q9: (F0) [W7] @HLOOKUP(Q$7+$L9*7,C7..J9,$N9)*90/200

          L    M N  OP    Q       R       S       T       U       V       W
1
2
3
4      # WKS
5
6    SOW TO IOFF-I
7     SALE   ISET I 31-Mar 07-Apr 14-Apr 21-Apr 28-Apr 05-May 12-May
8    -------I----I-----------------------------------------------------------
9          9 I   2 I      11       0       11       0       9       0       9
10
11
12
```

Figure 5. Continuation of spreadsheet in Figure 4 (see text for explanation).

```
T9: (F0) [W7] @HLOOKUP(T$7+$L9*7,C7..J9,$N9)*90/200

          A       B    C       D       E         Q     RS    T       U       V
1
2                                SOWING SCHEDULE
3
4                                      QTY TO SELL 1986
5
6
7       VARIETY    I02-Jun 09-Jun 16-Jun          31-Mar 07-Apr 14-Apr
8    --------------I-------------------------  ------------------------------
9    Ageratum BlueI     25              25           11       0       11
10
11
12
```

Figure 6. Continuation of spreadsheet in Figure 4 (see text for explanation).

We also use the computer to track our production during the season by using what we call a "crop status" (Figure 7). We will look at our crop weekly and take a physical inventory and note the amount that will be ready to sell in 1 week, 2 weeks, 3 weeks, 4 weeks, and the quantity that has just been planted. By knowing what you have projected to sell, you can determine if you are maintaining the proper quantities of pots or flats by cultivar.

E8: +D8-C8

	A	B	C	D	E	F	G	H	I
1			P4 CROP STATUS FLOWERING						
2									
3									
4		I	1st TWO WEEK PERIOD			I	2nd TWO WEEK PERIOD		
5		I				I			
6	VARIETY	I	EXPECTED	ACTUAL	+/-	I	EXPECTED	ACTUAL	+/-
7									
8	Ageratum	I	2100	5200	3100	I	2100	0	-2100
9									
10	Alyssum	I	1950	600	-1350	I	1950	3200	1250
11									
12	Begonia	I	938	0	-938	I	938	3200	2263

Figure 7. Crop status spreadsheet used to track production during the season.

The examples that I have given are all designed for bedding plants because that is where I have the most experience. But scheduling is the same no matter what the crop. What I wanted to do today was to introduce you to spreadsheets, to show you that they are easy to use, and since you start out with essentially a blank sheet of paper, the possibilities are endless.

RALPH SHUGERT: A question for Mike Dunnett. Is your plant, scabious butterfly blue, available in the U.S.

MIKE DUNNETT: A simple answer is—no, but we are always interested in considering any offers.

VOICE: Could you say something about the flowering of your scabious butterfly blue?

MIKE DUNNETT: It is an herbaceous perennial. It flowers well the first year and for a number of years after that. It could be used as a perennial bedding plant. It shows color from April until October in England. It does not require a winter-chilling period. In a warmer climate it would probably flower continuously.

VOICE: What did your promotional efforts cost you in bringing out this plant?

MIKE DUNNETT: It cost in the first year 27 pence (30 or 40 cents) per plant. This, times 70,000 plants gives about $24,500, not

including my time and that of the other directors of the firm.

KIRK CLARK: This is to Loren Oki. Have you put into your spreadsheet a "fudge factor"?

LOREN OKI: Yes, the calculations are very precise, but we also use a "production factor" of 10%, which indicates more transplantable plants than we calculate.

JAPANESE MAPLE PROPAGATION AT MONROVIA NURSERY

STEVEN A. HOTTOVY

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Dayton, Oregon 97114

The numerous cultivars of Japanese maples, *Acer palmatum*, comprise an interesting group of desirable landscape plants. Their variations in leaf form, color, and habit, merit special placement in the landscape. To preserve these characteristics, Japanese maples are traditionally grafted on to seedlings of *Acer palmatum*.

At Monrovia Nursery Company, we are propagating the cultivars by grafting and budding. The propagation method used is determined by the time of year and the size of the scion and rootstock. During late winter, stick budding and side cleft grafts are utilized. In the late summer, chip budding is used.

Stick-Budding. Stick-budding uses a small stick with several sets of buds as a scion. The rootstock must be actively growing and in the bark slip stage for a successful union. This method is particularly useful if there is a caliper difference between scion and rootstock.

In late winter, dormant seedling *Acer palmatum* rootstocks of approximately pencil thickness are brought into a greenhouse held at 72°F. Kept thoroughly watered in this warm environment, the seedlings quickly resume growth and enter the bark slip stage, usually in about three weeks. A color change or "greening" of the stems is a good indication. As the upper buds swell and begin to break it is time to stick-bud.

Dormant leafless scions are collected from container-grown stock. The scions can be held in cold storage for several days if wrapped in damp newspaper.

The grafter cuts a 1 in. T-bud cut near the base of the rootstock. This bark is opened by slipping the budding blade under the bark. The scion is formed using a shallow 1 in. cut on one side and a short basal nick on the opposite side. The scion is slipped into the open T-bud matching the long shallow cut. Clear plastic chip bud tape

including my time and that of the other directors of the firm.

KIRK CLARK: This is to Loren Oki. Have you put into your spreadsheet a "fudge factor"?

LOREN OKI: Yes, the calculations are very precise, but we also use a "production factor" of 10%, which indicates more transplantable plants than we calculate.

JAPANESE MAPLE PROPAGATION AT MONROVIA NURSERY

STEVEN A. HOTTOVY

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12600 SE Alderman Road
Dayton, Oregon 97114

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(0.002 × ½") is used to secure the graft. The entire scion is covered by wrapping, tying at the top. The grafts should knit in about one month. The chip bud tape is removed prior to any scion bud sprouting. When the chip bud tape is removed, a small piece of masking tape is placed around the base of the graft to protect the union. When the scion's new growth reaches the several leaf stage, the upper rootstock is removed above the graft union. After further growth of the scion, the plants are moved outside to be hardened off prior to being canned into one gallon containers.

Side Cleft Graft. Side cleft graft uses a scion with several sets of buds similar to the stick bud but usually the wood is of larger caliper. This method also requires the rootstock to be actively growing but the "bark slip stage" is not critical. Side cleft graft is useful when the scion and rootstock are of similar caliper.

In late winter, dormant seedling rootstock is moved into a greenhouse to begin active growth. When the upper buds start to swell the seedling is ready to graft. Dormant leafless scionwood is collected in the field, trying to match rootstock caliper closely.

The grafter makes a 1 in. diagonal cut down into the rootstock near the base. The scion is formed by making identical 1 in. cuts on opposite sides of the wood that taper to the base. This wedge shaped scion is inserted into the side cleft of the rootstock and the cambiums lined up. Only the graft cut is wrapped. A rubber budding strip is used to secure it. The rubber strip and any exposed cuts are painted with a thin coat of tree paint. The grafts are placed in poly tents at 78°F to knit. After approximately one month, the grafts will have knitted sufficiently for scion growth to begin. The tents are gradually vented to harden off the new growth. When the scion growth reaches the several leaf stage, the rootstock is cut back to the graft. The plants are grown on as previously mentioned.

Chip Budding. Chip budding uses a single bud removed from the scion with a chip of wood. The rootstock must be actively growing for a successful union. This method is particularly useful in producing a single stem whip for tree production, or when scionwood is limited.

In August, seedling *Acer palmatum* rootstocks in the field are graded to pencil thickness and the lower leaves and branches are removed.

Actively growing scions are collected from container-grown stock. Care is taken to match the size of the wood to rootstock. The scion is defoliated by trimming the leaves off, leaving a small stub of petiole to protect the bud. The scions are wrapped in damp newspaper and stored briefly in a cool place. It is important to use the scion as currently as possible.

The grafter selects a smooth, straight area, low on the rootstock. The first small cut is made across the stem at about a 30° angle, to a depth of ⅓ the stem. The second cut is made 1 in. above

the first, angling down to connect with it. The chip of rootstock is removed and discarded.

Identical cuts are made on the scion to remove the desired bud. The bud should be centered on the chip. The bud chip is placed in the rootstock, resting on the lip of the prior cuts. Cambiums match easily if the wood is of similar caliper. The chip bud is wrapped with the chip bud tape, covering the entire bud, tying above the bud. The buds knit in 30 to 35 days. When a small ring of callus is noticeable around the edge of the chip bud, the tape is removed. The budded rootstock is allowed to go dormant in fall.

In February, the upper rootstock is pruned back just above the chip bud. The cut should angle away from the chip bud to prevent the spring sap flow from "drowning" the bud. As the days warm, the bud breaks, producing a single stem whip. When the shoot from the bud is about one foot tall, it is staked. The first season, the main emphasis is on producing height in the maple. The second season the main emphasis is on building caliper and branching.

By utilizing these three methods of Japanese maple propagation, we can spread the work load for the grafting crew, and produce "Distinctively Better" Japanese maples in containers.

GRAFT INCOMPATIBILITY: EFFECT OF CYANOGENIC GLYCOSIDES ON ALMOND AND PLUM CALLUS GROWTH

CHARLES W. HEUSER

Department of Horticulture
The Pennsylvania State University
University Park, Pennsylvania 16802

Abstract. The effects of the cyanogenic glycosides, amygdalin and prunasin, and their breakdown products, cyanide and benzaldehyde, on callus from 'Marianna 2624' plum (*Prunus cerasifera* Ehrh. × *P. munsoniana* Wight & Hedr.), and on that from two almond cultivars (*P. dulcis* Mill. 'Nonpareil' and 'Texas') were compared. Prunasin inhibited the growth of 'Marianna 2624' plum and 'Nonpareil' almond callus but not 'Texas' almond. Amygdalin inhibited 'Marianna 2624' plum callus growth but promoted growth of both almond cultivars. All 3 cultivars were inhibited to the same extent by sodium cyanide; however, benzaldehyde was strongly inhibitory to 'Marianna 2624' plum callus at 0.05 mM, but a concentration of 5 mM was required to similarily inhibit growth of either almond callus. The greater sensitivity of 'Marianna 2624' plum callus to the cyanogenic glycosides and benzaldehyde suggests that benzaldehyde is an important factor in the almond/plum incompatibility.

Tissue compatibility or incompatibility in plants can be regarded as a physiological tolerance or intolerance, respectively, between the protoplasts of different cells (7). Although substantial research on stock/scion incompatibility has accumulated (4,8), little

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attention has been directed at mutual physiological influences underlying vegetative graft incompatibility.

Cyanogenic glycosides have been implicated as causal agents in graft incompatibility. Gur, *et al.* (3) concluded that the anatomical disturbance at the union of incompatible pear/quince graft combinations was caused by seasonal inactivation of the cambium, due to toxic substances liberated by hydrolysis of prunasin near the union. Similarly, Gur and Blum (2) suggested that the accumulation of toxic hydrocyanic acid, which was liberated by hydrolysis of prunasin, causes the death of tissues at the peach/almond graft union in incompatible combinations. Breen (1), however, reported that cyanogenesis was not closely linked with the incompatibility between peach and plum because the prunasin concentration in the peach scion and plum rootstock remained relatively stable even as incompatibility symptoms increased in severity.

In this research, I examine indirectly the possible involvement of cyanogenic glycosides and their catabolites in the almond/'Marianna 2624' plum incompatibility by determining their effects on growth of callus cultures derived from almond and plum.

MATERIALS AND METHODS

Callus culture. Callus cultures were established from nodal explants taken from sections of current season's growth of greenhouse-grown 'Nonpareil' and 'Texas' almonds, and 'Marianna 2624' plum. Cultures were initiated and maintained on Murashige and Skoog salts (9) and the following, in mg/liter: myo-inositol, 100; nicotinic acid, 0.5; pyridoxine HCl, 0.5; thiamine HCl, 0.1; 2,4-D, 1.0; kinetin, 1.0; casein hydrolysate, 200; sucrose, 30,000; and Difco Bacto-agar, 7,000. The pH was adjusted to 5.6 ± 0.1. Erlenmeyer flasks (125 ml) were used as stock culture vessels; each flask contained 50 ml culture medium. Stock cultures were maintained at 26°C under 6 μmol $sec^{-1}m^{-2}$ (cool white fluorescent lamps, F48T12·CW·HO) for 24 hr daily.

Callus assays were carried out in 120 ml wide mouth, French-square bottles fitted with plastic caps without liners. After sterilization, 10 ml of culture medium was added to each sterile bottle. One piece of callus of approximately 15 mg was transferred to each bottle using sterile technique. The bottles were kept in a lighted incubator as above for 30 days. Ten replicates were used for each treatment. Calli were weighed at the end of the period.

Amygdalin and prunasin experiment. Individual cyanogenic glycosides were added at 1 and 2 mM. The pH of the medium was adjusted to 5.6 ± 0.1 after addition of the cyanogenic glycoside and prior to filter sterilization.

Sodium cyanide experiment. Sodium cyanide (NaCN) was added at 0.1, 0.5, 1 and 2 mM before pH adjustment and filter sterilization.

Benzaldehyde experiment. Benzaldehyde was added at 0.01, 0.05, 0.1, 0.5, 1.0 and 5.0 mM after pH adjustment and filter sterilization.

Statistical analyses. Effects of amygdalin and prunasin were evaluated using orthogonal comparisons. Effects of NaCN and benzaldehyde were evaluated using Scheffe's test (5% level).

RESULTS

Amygdalin and prunasin experiment. Amygdalin promoted callus growth of 'Texas' and 'Nonpareil' but inhibited growth of 'Marianna 2624' (Table 1). The difference between the control and the mean of the amygdalin treatments was significantly different from 'Texas' ($P = 0.05$, $F = 6.83$) but not 'Nonpareil' using orthogonal comparisons between control and amygdalin treatments (1 and 2 mM). Both almond cultivars showed increased fresh weight with 2 mM amygdalin. There was a significant effect with the 2 amygdalin concentrations for 'Nonpareil' ($P = 0.05$, $F = 6.7$) but not 'Texas'. In contrast, the growth of 'Marianna 2624' was significantly reduced by the amygdalin treatments. The difference between the control and the mean of the amygdalin treatments was significantly different ($p = 0.01$, $F = 239.5$), and there was a significant effect for the 2 amygdalin concentration ($P = 0.05$, $F = 5.49$).

Table 1. Influence of amygdalin and prunasin concentration on fresh weight of callus cultures from 'Marianna 2624' plum, and 'Texas' and 'Nonpareil' almonds.

Callus culture	Mean fresh weight (g/culture)		
	Amygdalin conc. (mM)		
	Control	1	2
'Nonpareil'	2948.3	2706.1	3807.2
'Texas'	636.4	1083.5	1035.5
'Marianna 2624'	754.7	158.2	31.7
	Prunasin conc. (mM)		
	Control	1	2
'Nonpareil'	2165.3	1751.0	1786.1
'Texas'	669.6	680.1	673.3
'Marianna 2624'	956.5	20.5	16.9

Prunasin inhibited callus growth of 'Nonpareil' and 'Marianna 2624' but did not affect 'Texas' callus growth (Table 1). Prunasin at both 1 and 2 mM severely and equally inhibited the growth of 'Marianna 2624' callus. The difference between the control and the mean of the prunasin treatments with 'Marianna 2624' was significantly different ($P = 0.01$, $F = 88.71$) using orthogonal comparisons. 'Marianna 2624' did not show a significant effect for the 2 prunasin concentrations and prunasin was more inhibitory than amygdalin. Callus from 'Nonpareil' was significantly inhibited ($P = 0.01$, $F = 22.7$) at the higher concentration (2 mM) but not lower

prunasin level, and callus growth of the control was significantly different (P = 0.01, F = 11.18) from the mean of the 2 prunasin concentrations using orthogonal comparisons. 'Texas' callus growth was unaffected by the presence of prunasin. There was no difference between the control and the mean of the 2 prunasin concentrations, nor between the two prunasin concentrations.

Sodium cyanide experiment. All 3 cultivars were inhibited to the same extent by 2 mM NaCN, although cultivar differences were observed over the range of concentrations tested (Table 2). Mean separations using Scheffes test (5% level) showed the following in the NaCN study. With 'Nonpareil' treatments up to 1 mM were not different. A break occurred above 1 mM, and 2 mM NaCN was different from the lower concentrations. Callus fresh weight means for 'Texas' not significantly different from each other include: 0 and 0.1 mM; 0.1, 0.5 and 1.0 mM; and 0.5, 1.0 and 2.0 mM. With 'Marianna 2624' 1 and 2 mM NaCN were different from all lower concentrations and from each other.

Table 2. Influence of sodium cyanide concentration on fresh weight of callus cultures from 'Marianna 2624' plum, and 'Texas' and 'Nonpareil' almonds.

Sodium cyanide conc (mM)	Mean fresh weight (g/culture)		
	'Nonpareil'	'Texas'	'Marianna 2624'
Control	3957.5a[1]	1304.0a	1100.5a
0.1	3879.0a	1046.6ab	952.4a
0.5	3483.7a	836.0bc	906.2a
1.0	3566.9a	712.9bc	647.3b
2.0	1386.2b	496.6c	360.7c

[1]Means followed by the same letter or letters are not significantly different.

Benzaldehyde experiment. The response of the almond cultivars to benzaldehyde was distinctly different from that of 'Marianna 2624' (Table 3). Benzaldehyde at 0.05 mM inhibited growth of the 'Marianna 2624' callus, but a hundred fold greater concentration was required to elicit a similar level of inhibition with the almond cultivars. Mean separations using Scheffe's test (5% level) showed the following in the benzaldehyde study: 'Texas' callus fresh weight means at 0.5 and 1.0 mM benzaldehyde were significantly different from all lower concentrations and the highest level, 5 mM, was significantly different from all other concentrations. Callus fresh weight means for 'Nonpareil' not significantly different from each other include: 0, 0.01, 0.05 and 0.1 mM; 0.05, 0.1 and 0.5 mM; and 0.5 and 1.0 mM. Benzaldehyde at 5 mM was different from all lower concentrations with 'Nonpareil'. With 'Marianna 2624' fresh weight means at control and 0.01 mM were different from all higher concentrations which were not different from each other.

Table 3. Influence of benzaldehyde concentration on fresh weight of callus cultures from 'Marianna 2624' plum, and 'Texas' and 'Nonpareil' almonds.

Benzaldehyde conc (mM)	Mean fresh weight (g/culture)		
	'Nonpareil'	'Texas'	'Marianna 2624'
Control	3236.0a[1]	1072.4a	831.2a
0.01	3179.8a	1295.8a	901.5a
0.05	2706.8ab	1121.6a	35.4b
0.1	2525.3ab	1113.3a	26.9b
0.5	2225.1bc	719.1b	17.1b
1.0	2036.3c	587.6b	14.8b
5.0	32.2d	26.5c	14.4b

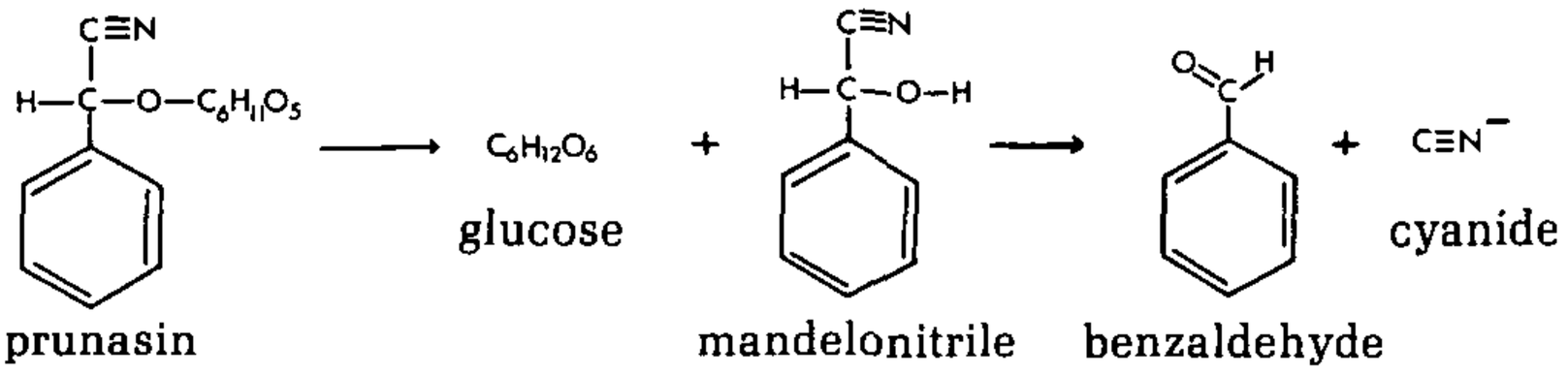
[1]Means followed by the same letter or letters are not significantly different.

DISCUSSION

In the present study both cyanogenic glycosides, amygdalin and prunasin, severely inhibited callus growth of 'Marianna 2624' plum. However, neither cyanogenic glycoside inhibited 'Texas', a cultivar that forms a compatible combination with 'Marianna 2624' plum. 'Nonpareil', which is not compatible with plum, showed a 77% inhibition at 2 mM prunasin but not with amygdalin. The increased growth observed with amygdalin in the almond cultures suggests that the callus was able to metabolize this compound. Unpublished results from our lab have shown that both cultivars contain low levels of an enzyme capable of hydrolyzing amygdalin.

The greater sensitivity of 'Marianna 2624' plum callus to applied cyanogenic glycosides is interesting since both the almond scions (1) and the plum understock (2) contain the cyanogenic compound prunasin. In the peach/almond incompatibility system it was reported that almond types with a low cyanogenic glycoside content also have a low ability to hydrolyze cyanogenic glycosides, even when additional glycoside is supplied by the peach scion (2).

Cyanogenic glycosides do not directly cause the incompatibility but must be decomposed to release a toxic product (2,3). It is well established that plants containing cyanogenic glycosides contain enzymes capable of decomposing them and it has previously been reported that shoot tissue of 'Marianna 2624' contains an enzyme capable of hydrolyzing cyanogenic glycosides (5). The enzymatic hydrolysis of prunasin proceeds consecutively in a two-step process: prunasin is hydrolyzed to mandelonitrile and glucose; mandelonitrile is hydrolyzed to HCN and benzaldehyde:



prunasin mandelonitrile benzaldehyde cyanide

Of the 3 breakdown products (glucose, HCN and benzaldehyde) only HCN and benzaldehyde could be considered as potential toxic products. Hydrocyanic acid has been shown (3) to cause the anatomical disturbance at the union of the incompatible pear/quince combination. Hydrocyanic acid, liberated from prunasin, also has been implicated in the incompatibility between peach scions and almond roots (2).

Cyanide, however, inhibited the almond or plum cultivars equally (Table 2). At the highest level of cyanide (2 mM) all 3 cultivars were inhibited to approximately the same extent: 32%, 35% and 38% for 'Marianna 2624', 'Nonpareil', and 'Texas', respectively. This indicates that cyanide is not the sole toxic breakdown product of prunasin or amygdalin inhibiting plum callus growth, as was found with the pear/quince incompatibility (3) or proposed in the peach/almond (2) incompatiblity. The lack of severe cyanide toxicity may indicate that all 3 plants are capable of metabolizing HCN into amino acids as has been reported with many plants.

Benzaldehyde stopped all growth of plum callus at 0.05 mM, but a 100-fold greater concentration was required to cause a similar growth reduction of the almond cultivars (Table 3). The greater sensitivity of 'Marianna 2624' plum callus to benzaldehyde indicates that it is a major hydrolytic product from prunasin inhibiting plum callus growth.

Almond interclonal differences in incompatibility with 'Marianna 2624' plum are apparently inherited. Kester, *et al.* (6) reported that almond cultivars incompatible with 'Marianna 2624' were seedlings of 'Nonpareil' or had a genetic relationship to it. Most of the compatible combinations had a known or suspected relationship to 'Texas.'

The incompatibility reaction between almond and plum also has been reported to be of the translocated type, characterized by phloem degeneration and failure of a mutually compatible interstock to overcome the incompatibility (1,6). Kester, *et al.* (6) suggested from their studies on the compatibility reaction between almond and 'Marianna 2624' that the incompatible scion produced a factor which is translocated in the phloem to the graft union where it produces a toxic reaction with the rootstock.

The mechanism allowing 'Texas' callus to grow in the presence of the two naturally occurring cyanogenic glycosides is unknown, however, it may be the same factor responsible for the successful graft union of this cultivar with 'Marianna 2624' understock. Callus from the understock 'Marianna 2624' appears to have a greater sensitivity to added cyanogenic glycosides and benzaldehyde. This sensitivity suggests that cyanogenesis should be examined as a causal factor in the almond/plum incompatibility.

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AIR LAYERING: AN ALTERNATIVE METHOD FOR THE PROPAGATION OF *MAHONIA AQUIFOLIUM* 'COMPACTA'

RICK WELLS

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Azusa, California 91702

At the 1985 IPPS, Western Region meeting, Dennis Connor of Monrovia Nursery Co. reported (1) on the production of *Mahonia aquifolium* 'Compacta' via cutting and tissue culture. Since then we have conducted an experiment to determine whether this plant could also be propagated utilizing air layering techniques.

Air layering is an ancient and, under favorable conditions, a very sure method of plant propagation for many plants. This method has been practiced in China and other Asian countries for thousands of years. The method has been used mostly with plants native to the tropics and subtropics; however, some hardy perennial plants such as dogwoods, hemlocks, hollies, rhododendrons, viburnums, and wisterias have also been propagated in this manner.

Basically the method involves the stimulation of root develop-

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Basically the method involves the stimulation of root develop-

ment by injuring a stem and surrounding the wound with a medium which is porous enough to admit sufficient air and yet will remain moist enough to provide a good environment for root growth.

In our experiment we tested ten different methods involving different types of cuts, rooting media, and hormones. Several of the methods resulted in 100% rooting, but the following procedure was chosen as best to be used in full scale production.

We are air layering plants in #1, #2, and #5 containers, as well as stock plants growing in the ground. In either case, the process begins by first selecting the branches to be air layered and stripping all leaves from a 5 to 6 in. long section of the stem. This would normally leave a 6 to 9 in. tip extending above the point to be rooted. On long branches, two air layers may be made on the same branch. The wood must not be too soft. Well-ripened, one-year-old wood is ideal, but two year and older wood may also be rooted.

A wound is made in the center of the defoliated section by making a ¾ in. long upward cut into the wood about ⅛ in. deep. A small amount of sphagnum moss, which has been soaked in a 60 ppm IBA solution, is placed under the resulting flap. Then some additional moist moss is placed around the area to form a small ball approximately 2 in. in diameter and 3 in. long. It is important that as much water as possible is wrung out of the moss so as to prevent decay.

Once the moss is in place the area is covered with polyethelyne wrap (two layers) and tied with a Twistum at the top only. The top is tied to help prevent water from running down the stem and into the moss, since most of the plants are watered by overhead irrigation. Finally, the plastic wrap is covered with a piece of aluminum foil. This is done to help prevent overheating within the plastic.

This process is normally done by a two-person team with each team completing approximately 600 air layers per eight hour day.

Some rooting can be seen in as little as four weeks. However, the newly-rooted plants are not ready for removal for six to eight weeks. Once a large mass of roots can be seen under the plastic, the new plants may be severed from the mother plant. The plastic wrap is then removed and the plant is canned directly in a #1 container. Within eight weeks, roots can be seen at the bottom of the container and about a year later the new plant will be tall enough to be air-layered itself.

The air-layering of mahonias can probably be done any time during the year; however, we try to do them in the late summer and early spring. Plants rooted in the late summer may be canned during the winter when it is cool and plants done in early spring may be canned prior to the hottest part of the summer. Losses during canning have been surprisingly low, (less than two percent).

During these times of "modern" propagation techniques, we must not forget some of the old tried and true methods; for many

plants these old methods are still best.

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CAMELLIA GRAFTING AT MONROVIA NURSERY

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Camellias are one of the major crops at Monrovia Nursery. We prepare in the neighborhood of 1,500,000 camellia cuttings per year resulting in the production of over 1,000,000 liners. Approximately 600,000 of these liners are used for the production of larger containers while the rest are sold as liners. Of the 600,000 or so #1 container plants produced each year, only about 5,000 are grafted, (this is only about 0.8%).

We graft camellias for one of three reasons. First some cultivars ('Pink Pagoda' for example) are very poor rooters or grow poorly on their own roots. Second, we can multiply new cultivars faster by utilizing both softer cuttings and heavier scionwood from the plants where cutting wood is limited. Third, when we receive wood of the new cultivars from other nurseries or arboreta the wood is often unsuitable for cuttings, but better suited for scionwood.

Camellias require considerable care during the grafting process. We have had the best results utilizing the following procedure. For understock, we use strong growing cultivars (usually Debutante) grown in #1 containers and produced by cuttings. The caliper of the understock should be about ¼ in. diameter. To produce a plant of suitable size for understock it takes approximately 2½ years from the time of making the cuttings. Understock is hand selected and must not be too low-branched; it should have a straight base with little or no side branching for the first 4 to 5 in. above the soil. Many times, the best understock are the plants which are a little too "leggy" to be kept for growing on. Selecting them to be grafting understock makes good use of them.

Understock is brought into the greenhouse during the middle of December, about two weeks prior to grafting. Because of winter rains, the understock usually comes into the house quite wet. It often takes two weeks for the understock to dry enough to be suitable for grafting. We have found that if the soil is too wet, the plant will "bleed" heavily, which will interfere with callusing and contribute to disease problems at the graft union.

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The greenhouse environment is very important. Camellias should be kept cool; heating is only provided if night temperatures fall below 40°F. Extra shade is provided by draping 55% shadecloth inside the greenhouse over the benches. Since the grafts are covered with clear glass jars, this extra shade is necessary to help prevent heat build-up in jars.

Once the understock has dried to a suitable point, grafting begins. Just prior to grafting all understock is sprayed with a 200 ppm Benlate spray. Since a cleft graft is used, the first step is to cut off the understock at a height of 2½ to 3 in. above the soil with pruning shears. Next, a fresh cut is made on the understock with a sharp grafting knife, removing a thin slice of wood and any damaged tissue resulting from the pruning shears. The first cut on the understock should not be flat, rather it should slope slightly to one side. Then a downward cut is made splitting the understock to a depth of about 1¼ in. This cut is made so that it bisects the angle of the first cut. In this way, one side of the vertical cut is through the high point of the understock. The understock is now ready for the scion.

Scionwood is collected from #1, #5, and #7 containers from last year's wood, although older wood may be used if necessary. Tips, seconds, and thirds are suitable. Scions are 3 to 3½ in. in length, containing 3 or 4 buds; shorter scions with only two buds may also be used if wood is in very short supply. Each scion should have two leaves (with the end ⅓ of the leaf removed). All other lower leaves are removed. Scions are washed in 200 ppm Physan, dipped in 200 ppm Benlate and stored in plastic bags at 40°F until needed. Camellia wood stores well and may be good for three weeks if stored in this manner.

The two cuts on the scion are 1 to 1¼ in. long. They should begin just below and on either side of one of the bottom buds, usually the second or third bud from the top. The bark left between the cuts should be slightly wider on the side below this bottom bud. Thus the scion base is slightly wedge-shaped. The very thin wood at the base of the scion should be removed since it is most susceptible to drying and desiccation.

Once the scion is prepared, it is placed in the understock so that the bottom bud faces out and is placed at the top of the sloping cut of the understock. Care should be taken to match the cambial areas of the scion and understock. Pulling the scion up so that ¼ in. of the cut can be seen above the understock often simplifies the matching process as well as providing a good visual area to check callus formation. The graft is then wrapped with a ¼ × 4 in. grafting rubber; no sealing is required. Lastly the entire graft is sprayed with a 200 ppm Benlate spray.

Wide mouth quart jars are used to cover each grafted plant. They provide each plant with its own mini greenhouse environ-

ment where a clean, high humidity condition can be maintained. Jars are washed and dipped in Physan prior to use.

By the third week after grafting, good callus formation can be seen; by the fourth week the buds on the scions begin to elongate and unfold. This is a critical time to watch for jar removal. At the first sign of bud unfolding, the jar should be tipped to provide some air circulation and start the hardening-off process for the graft. The jar may be completely removed two or three days after tilting. If leaves are allowed to unfold in untilted jars, the new scion will usually wilt badly and sometimes even die when the jar is removed. Light hand misting may be necessary on warm days to prevent wilting. Two to three weeks after jar removal, the plants may be taken outside and placed in a shade house where they again may require hand misting on warm days for awhile.

By the following spring, one year later, the grafted plants are ready for shifting to larger containers.

This method has worked well for us for many years. The most important things to remember are to keep the grafts dark, cool and dry, and to be sure to remove the jars before leaves unfold.

RECENT ADVANCES IN THE PROPAGATION OF WOODY PERENNIALS

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Abstract. Major advances have emerged in methods for cloning, creating new genetic variation (directed and misdirected), and in risk reduction associated with the vegetative propagation of woody perennials. These advances are related mainly to the capturing of specific genetic gains. Advances will be illustrated with wood ornamentals, forest (pine, fir, spruce) and fruit trees (peach, cherry, pistachio).

INTRODUCTION

Apart from classical and traditional methods of plant propagation (8,15), the emphasis in this review will be on more recent cloning procedures based on cell and tissue culture (4,5). Recent advances in propagation reflect three categories of trend. First, for cloning procedures, somatic embryogenesis in cell suspensions for mass propagation is increasingly being considered as an alternative or supplemental method to micropropagation (6). The trend with micropropagation and somatic embryogenesis is to apply these precedures to explants from mature trees. Second, methods are now available to create new genetic variation with long-lived woody

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perennials, e.g., regeneration of sandalwood from protoplasts, the genetic engineering of cells capable of somatic embryogenesis, and aberrations from true-to-type gene expression (somaclonal variation) (7). With fruit trees and ornamentals, genetic variation is often considerably less than with our native forest trees. For the latter, the trend is towards domestication of the existing genetic variability. Third, computer-assisted mechanization and marketing coupled with improved diagnostic and prognostic methods are sought for product quality control, the reduction of risks, and lower production costs. This trend is reflected by the emergence of enterprises in biotechnology that fully integrate all nursery operations with well-established marketing and sales.

Cloning procedures. Numerous incremental advances in the micropropagation of woody perennials are evident in recent books (2,3,4,5,10). Researchers have attempted to gain greater control of somatic embryogenesis as an alternative to micropropagation because:

1) greater numbers of propagules are based on cellular multiplication rates rather than on separate root and shoot multiplication rates.
2) ease of handling of cells, encapsulation, low temperature storage of somatic embryos, and potentially mechanized production of tissue-culture derived plants.
3) better process control, e.g. pH, gas exchange, temperature, uniformity of environment, early system diagnostics, etc.,
4) ease of scale-up and long-term storage of cell lines with improved prospects for process synchronization, and
5) easier application of principles and novel methods of agricultural biotechnology to uniform cell suspensions (e.g. protoplast fusion, recombinant DNA methodology, etc.)

Somatic embryogenesis in conifers has now been achieved with *Picea abies* (14), and *Larix* (19). More recently, our laboratory has defined the process of conifer-type somatic polyembryogenesis in Douglas-fir, loblolly pine, sugar pine and Norway spruce (13, and unpublished data). These approaches may be especially useful for high-value specimens for the Christmas-tree and ornamental market. Improvements in the cost-effectiveness of this technology are needed to mass propagate forest trees of low individual value.

Another advancement in cloning methods is the work with difficult-to-root mature woody perennials (30-to-100-year-old trees) (12). Our approach recognizes and extends earlier observations in France by AFOCEL scientists. For all conifers, the medium, method of surface sterilization, shoot and root production have been improved to more attractive levels. Micropropagated conifers are now being field-tested in several countries.

Micropropagation, based on explants from mature donors, facilitates the capturing of proven genetic gains of locally adapted populations. Furthermore by cloning mature and proven trees we may reduce our dependence on juvenile-mature correlations for the expression of elite traits. With seeds from controlled crosses (e.g. from seed orchards) the time needed to provide suitable explant material can be reduced by nearly one week by germination in controlled atmospheres.

The control of plant development by plant growth regulators may soon be approached in a very different way with the discovery of oligosaccharins (1). Oligosaccharins, or cell wall fragments, have plant growth regulator activity in cell and tissue culture systems. However, before this new class of substances becomes useful, the factors giving the morphogenetic responses need to be defined chemically, extended to a wider range of plants, and available commercially on an economic scale.

Expressions of totipotency in explant for cell and tissue culture are being exploited in four directions: 1) wide expression of totipotency with limited-to-random control as in micropropagation of fruit trees, 2) narrow expression with specific control as in somatic embryogenesis on conifer-type somatic polyembryogenesis, 3) replacement of the above by easy-to-root clones (azaleas, rhododendrons, forest trees), and 4) production of artificial seeds (18) from somatic embryos for storage at low temperatures to overcome poor seed years and to allow more time for progeny and field-testing (forest trees).

The useful and non-useful methods still have to be sorted out and established as cost-effective. In micropropagation, we can now begin to consider bypassing many of the constraints imposed by mature physiological states of explants. Problems in development remain such as vitrification, rooting, physiological preconditioning, and true-to-type clonal performance. We can expect new approaches to the control of development based on the exploitation of oligosaccharins.

New genetic variation. Attempts at genetically modifying plant cells are now widespread. It now seems surprisingly easy to modify the behavior of cells by microinjection, electroporation, protoplast fusion, induced mutations, etc. (*cf.* Proc. Intl. Hort. Congress, Davis, CA, 1986). However, the question remains: can we obtain useful clonal populations of plants from these genetically modified cells? The commercial answer to this question will take at least another decade. The answer may emerge from studies with the *totipotent cells showing true-to-type somatic embryogenesis.* Whenever possible, fully totipotent cells should be used in genetic modification so that the resultant new germplasm can be compared with industry standards. Unfortunately, we are still years away for developing a good delivery system for new cultivars based on the

above approaches. Nevertheless, progress is encouraging in the sense that new opportunities are seen in basic research where none existed before.

Risk reduction. At the completion of any cloning cycle, efficiency and quality control should be assured to protect the producer, consumer, and society. In clonal propagation, new diagnostic methods and biosensors especially for pathological situations (ELISA, mono- and polyclonal antibodies, radioimmunoassay, etc.) are being developed based on the relations in Figures 1 and 2 (8,16,17). Diagnostic methods, using principles and dogma identified by arrows, can also be applied to insects, pests, and diseases provided that methods are cost-effective, rapid, and reliable. Every indication exists that we will be able to certify trueness-to-type and disease-free stock through high-biotech methodology.

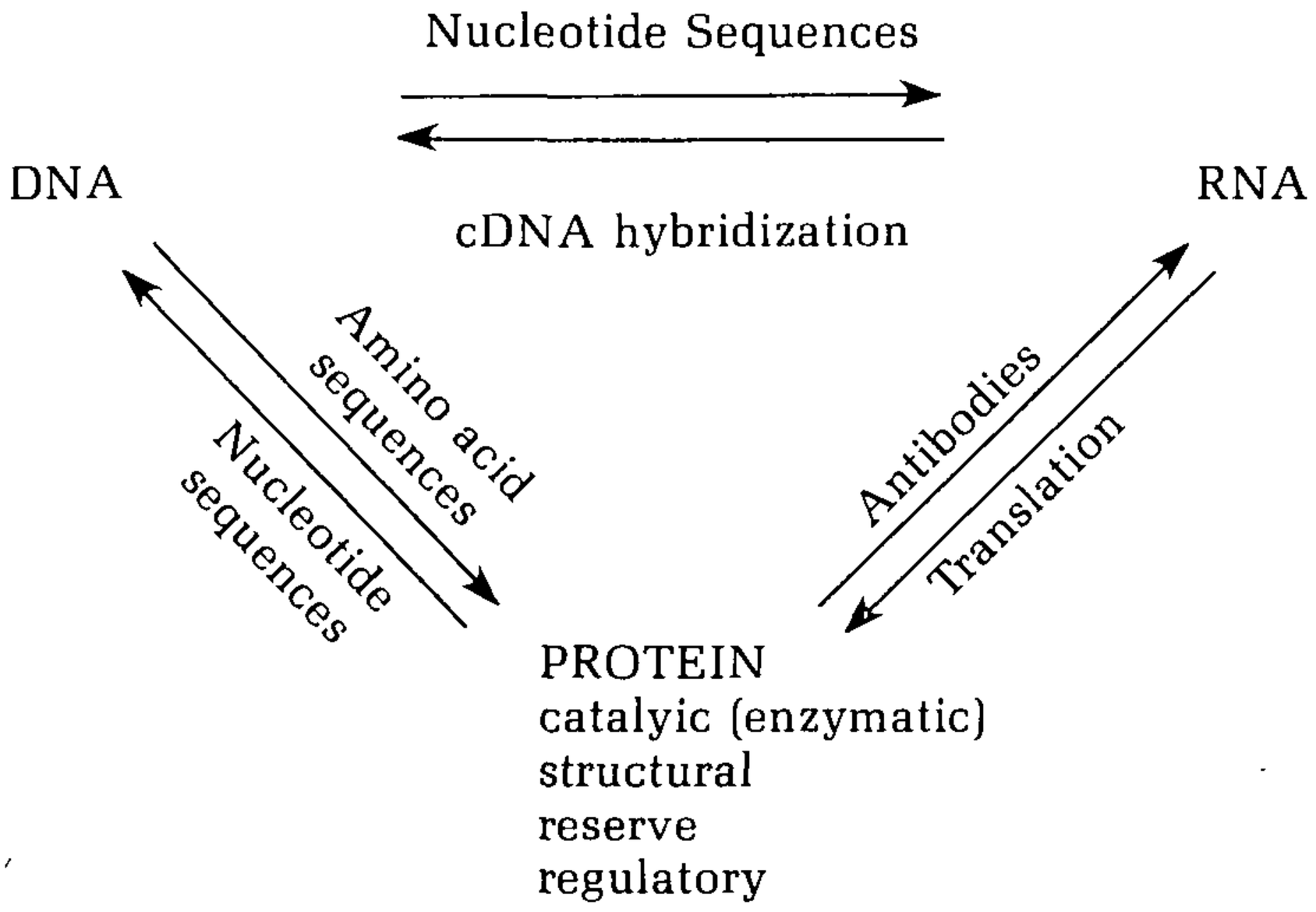

Figure 1. Interrelations among macromolecules (DNA, RNA, PROTEIN) associated with gene expression. Feedforward and feedback steps in process control are based on diagnostic criteria associated with arrows. These interrelationships provide the basis for dynamics shown in Fig. 2.

With woody perennials, the problem remains that the valuable attributes we seek to introduce, clone, and certify are usually found in difficult-to-propagate mature specimens. Gene expression in elite specimens are often based on very complex, long-lived, interactive and dynamic and heterotic genetic systems. In forestry, we are continually faced with the low individual production cost for propagules. Nevertheless, where valuable germplasm can be cloned, novel methods are now available to store encapsulated somatic embryos until performance testing is completed.

Recently, we have characterized gene expression in the developing pistachio fruit as a set of metabolic phenotypes at the experimental laboratory level (9). Our approach is based on the interrelations shown in Figure 2 for all stages of the life cycle.

This diagnostic method should provide sharper definitions of developmental processes in specific steps of cloning procedures. Definitions involve mathematical representations of physiological processes and strategies (algorithms) used by the clone in true-to-type gene expression. Notions of "process control" are based on time (physiological states and development), metabolic networks, and a quantitative description of the behavioral dynamics of the system in the solid, liquid, and gaseous phases.

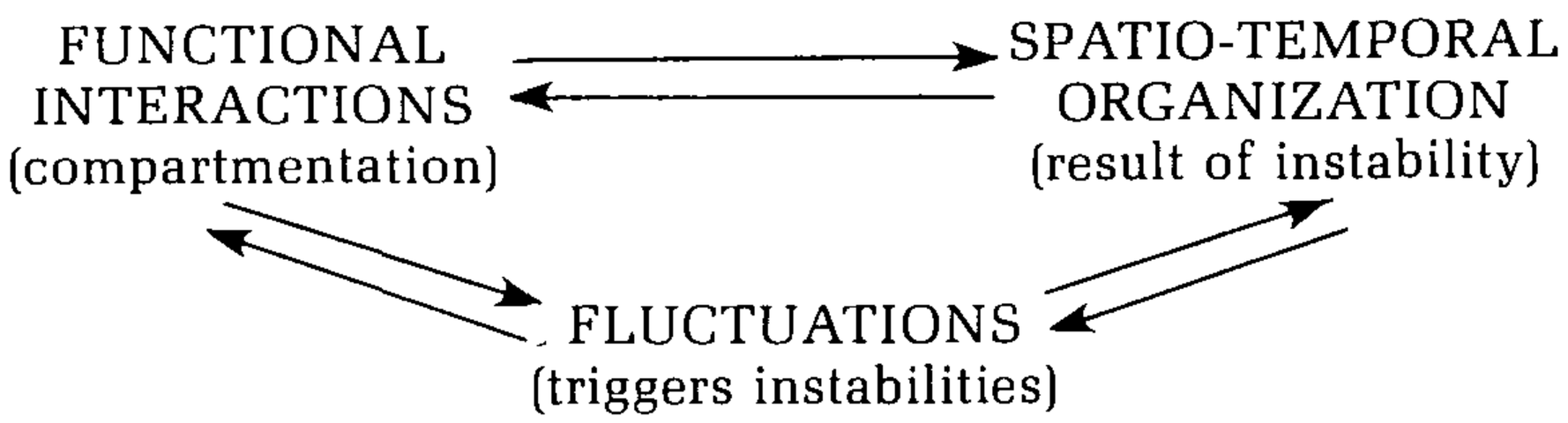

Figure 2. In cell and tissue culture, risk reduction should be based on a better understanding of gene expression and dynamics of growth and development of clonal materials. Dynamics arise from functional interactions among components of the system their spatio-temporal organization and their fluctuations. Functional interactions may include relation between exogenous (synthetic) and endogenous (naturally occurring) growth regulators calling into play new sets of gene activities that result in fluctuations and in the reorganization of cell potentials in the explant. Attempts have been made to capture these interactive properties and identify them on maps of metabolic phenotypes.

Metabolic phenotypes for clonal materials may someday be produced routinely to understand why some species remain recalcitrant and some processes unworkable. Unfortunately, metabolic phenotypes are yet of little value to the nursery where simple, single variable, specific, rapid cost-effective diagnosis is required. Phenotypes are an experimental tool more suitable for complex situations, involving many variables and dynamic interactive production systems critically focused on some aspect of quality control of a highly valued product (*cf.* Table 1).

Fortunately, metabolic phenotypes involving large-scale data arrays can now be compared, subtracted from one another or modified by computers to show more effectively the dynamics and efficiency of processes underlying gene expression. Phenotypic maps could include known factors and even factors based on yet unidentified, but useful, marker compounds for elite genes. Appropriate diagnostic methods for the computer assisted mechanization of the propagation process are not yet available.

Table 1. Values and attributes of diagnostic methods (Fig. 1) and metabolic phenotypes (Fig. 2) that relate to risk reduction (certification and quality control). Criteria for quality assurance may be realized with the aid of computer-aided chemistry and diagnostic reasoning.

Certification	*Attributes of Metabolic Phenotypes*
Insect-free	Distribution of key indicators
Pest-free	Kinematics and dynamics of problem
Disease-free	Precatastrophic indicators
True-to-type traits	Stability analysis
	Probabilistic scenarios
Quality Control	General vs. high specificity
Aberrant phenotypes	Ability to quantify physiological preconditioning
Synchronization	Process control logic
Scale-up	Plausible developmental algorithms
Cost-effectiveness	Plant-machine compatibility in clonal propagation

SUMMARY

While much of the recent progress in clonal propagation involves methods to capture genetic gains, mature trees and to improve quality control, they are not yet immediately or widely useful for plant propagation. Nevertheless, trends are in keeping with the practical needs of the propagator. In the long run, new genetic variation and biotechnological fixes will emerge based on recent advances that could lead to cost-effective, reliable, rapid and novel quality control technologies, especially for companies producing 5 to 10 million plants annually. Evidence is also emerging that some existing technologies in propagation can rapidly become obsolete because of improved biotechnology. We still need more examples and evidence for widely applicable, stable, and long-term procedures especially for woody perennials. Some examples should emerge from newly established biotechnology companies dealing with horticultural and forestry products or "green goods" in North American and in developing countries. All are continually threatened by limits in natural resources and by an economy challenged by currency, energy crises, and by natural and man-made catastrophes that lead inexorably to the high-grading of germplasm.

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INFLUENCE OF IBA CONCENTRATIONS ON ROOTING OF WOODY PERENNIAL NURSERY STOCK[1]

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Abstract. Cuttings of 20 woody genotypes belonging to various species were treated with 0 (control), 2,500, 5,000, 10,000, 20,000, and 40,000 ppm of indolebutyric acid (IBA) as a 5-second dip and rooted under intermittent mist. Except for two species (*Prunus serrulata* 'Kwanzan' and *Forsythia* × *intermedia* 'Lynwood Gold'), rooting of all plants was significantly greater than the control after treatment with one or more concentrations of IBA. Maximum rooting varied between 24 and 100% depending on the genotype. IBA-induced basal injury to cuttings occurred in all plants and increased with increasing IBA concentrations, especially between 20,000 and 40,000 ppm. In certain difficult-to-root genotypes, basal injury at these high IBA concentrations was associated with swelling and enhanced rooting above the injury.

It has long been known that high concentrations of certain growth regulators might promote rooting in hard-to-propagate species (3,10). In fact, IBA concentrations of between 10,000 and 40,000 ppm have been shown to stimulate rooting in some hard-to-root species, including various ornamental crabapples (3), *Tilia* spp. (11), *Quercus robur* 'Fastigiata' (7), *Cotoneaster acutifolius,* and *Taxus cuspidata* (5,6). In certain nursery propagation programs higher IBA concentrations are increasingly being used (1).

As part of a research program which aims to develop more effective methods and techniques for propagating nursery stocks (5,6), related investigations were conducted with a variety of other woody plants to determine their rooting response after treatment with different concentrations of IBA.

MATERIALS AND METHODS

Stem cuttings of current season's growth were rooted during the growing seasons between 1982 and 1985 from 20 woody species or cultivars, listed alphabetically with insertion dates and rooting period (weeks) in brackets:

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[1] Appreciation is extended to Joerg Leiss, Sheridan Nurseries Ltd., Oakville, Ontario for cuttings of several species, and to Bob Hamersma for technical assistance at the Horticultural Research Institute of Ontario, Vineland, Ontario.

[2] Present address: Ball-Superior Ltd., 1155 Birchview Dr., Mississauga, Ontario, Canada, L5H 3E1.

Acer platanoides 'Crimson King' (6/28/83 - 10)
Amelanchier laevis (6/23/83 - 5)
Betula pendula 'Gracilis' (6/25/82 - 13)
Chaenomeles speciosa 'Rubra' (7/10/85 - 4)
Elaeagnus angustifolia (7/30/85 - 6)
Euonymus alata 'Compacta' (6/27/85 - 5)
Forsythia × *intermedia* 'Lynwood Gold' (8/08/85 - 4)
Magnolia stellata (7/30/85 - 8)
Malus 'Bitenfolder' (8/11/83 - 7)
Malus 'Royalty' (6/25/82 - 5)
Prunus × *cistena* (8/09/85 - 4)
Prunus domestica 'Stanley' (7/18/85 - 7)
Prunus domestica 'Valor' (7/18/85 - 7)
Prunus domestica 'Verity' (7/18/85 - 7)
Prunus serrulata 'Kwanzan' (6/28/85 - 6)
Prunus triloba 'Multiplex' (7/19/85 - 5)
Quercus rubra (6/23/83 - 14)
Sorbus alnifolia (6/27/85 - 6)
Tilia cordata 'Glenleven' (6/29/83 - 4)
Tilia × *europaea* 'Pallida' (6/28/83 - 10).

Work was conducted at Macdonald College, McGill University, Ste-Anne-de-Bellevue, Quebec between 1982 and 1984. The study was completed at the Horticultural Research Institute of Ontario (HRIO), Vineland Station in 1985. Except for the three easy-rooting shrubs, *Euonymus alata* 'Compacta', *Prunus* × *cistena*, and *Forsythia* × *intermedia* 'Lynwood Gold', all other plants were difficult rooters.

Length of cuttings varied between 10 and 15 cm depending on genotype. The base of all cuttings were stripped of foliage. In cuttings with larger leaves, the leaves were cut in half to reduce the surface area and to facilitate closer spacing. Cuttings were treated (5-second dip) with 0 (control), 2,500, 5,000, 10,000, 20,000 and 40,000 ppm IBA dissolved in 95% ethanol. At Macdonald College, cuttings were inserted in a medium of 1 perlite: 1 vermiculite (v/v) and rooted in outdoor mist frames controlled by an electronic leaf. At HRIO, cuttings were inserted in a medium of 1 peat: 1 perlite (v/v), and rooted in outdoor frames under intermittent mist controlled during daylight hours by time clock (4 to 8 sec/8 min). At both locations, the mist frames were shaded with lath. Captan was applied as a drench at time of cutting insertion, followed by Captan or Benlate applied alternatively once per week.

The experimental design was a randomized complete block with four or five replications and 10, 12 or 15 cuttings per experimental treatment unit. Rooting performance of each genotype was based on percentage rooting and on a visual rooting index according to the scale: 0, no rooting; 1, callus but no roots; 2, poor rooting; 3, fair rooting; 4, good rooting; 5, excellent rooting.

RESULTS AND DISCUSSION

Data for percentage rooting of the 20 plants in response to varying levels of IBA are presented in Figures 1, 2, 3, and 4. Plants are shown in these figures in accordance with the peaking or plateauing of percentage rooting with low IBA concentration (2500 ppm, Figure 1); with intermediate IBA concentrations (5,000 to 10,000 ppm, Figure 2); with high IBA concentrations (20,000 to 40,000 ppm, Figure 3). Percentage rooting for the three easily-rooted shrubs are shown in Figure 4.

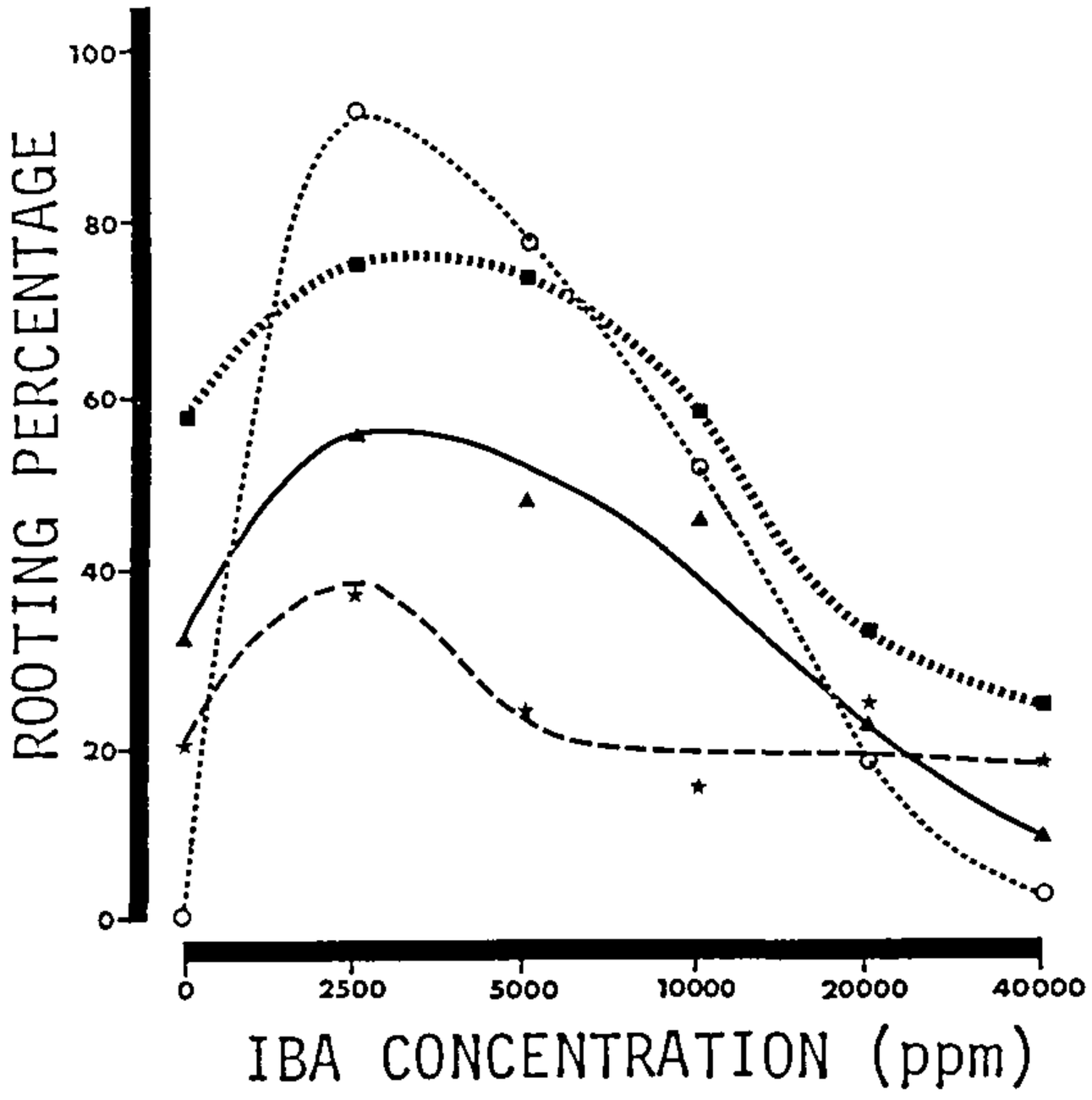

Figure 1. Plants with rooting percentage peaking at 2500 ppm IBA. LSD (P = 0.05): *Malus* 'Bitenfolder' (■), 22%; *Quercus rubra* (★), 13%; *Prunus serrulata* 'Kwanzan' (▲), 27%; *Tilia cordata* 'Glenleven' (○), 21%.

Except for *Prunus serrulata* 'Kwanzan' (Figure 1) and *Forsythia* × *intermedia* 'Lynwood Gold' (Figure 4), analysis of variance indicated that rooting of all other genotypes was significantly greater than the control after treatment with one or more concentrations of IBA. Maximum rooting varied between 99 and 100% in the easily-rooted shrubs (Figure 4) and between 24 and 91% in other genotypes (Figures 1–3).

The trend in data for percentage rooting in response to IBA concentrations and corresponding data for rooting indices (data not shown) varied similarly for all species. Chong (5,6) showed that, within a species, maximum rooting percentage, root length per cutting (RL), and root number per cutting (RN) may sometimes occur at different IBA concentrations. However, RL and RN were not evaluated in the present investigation.

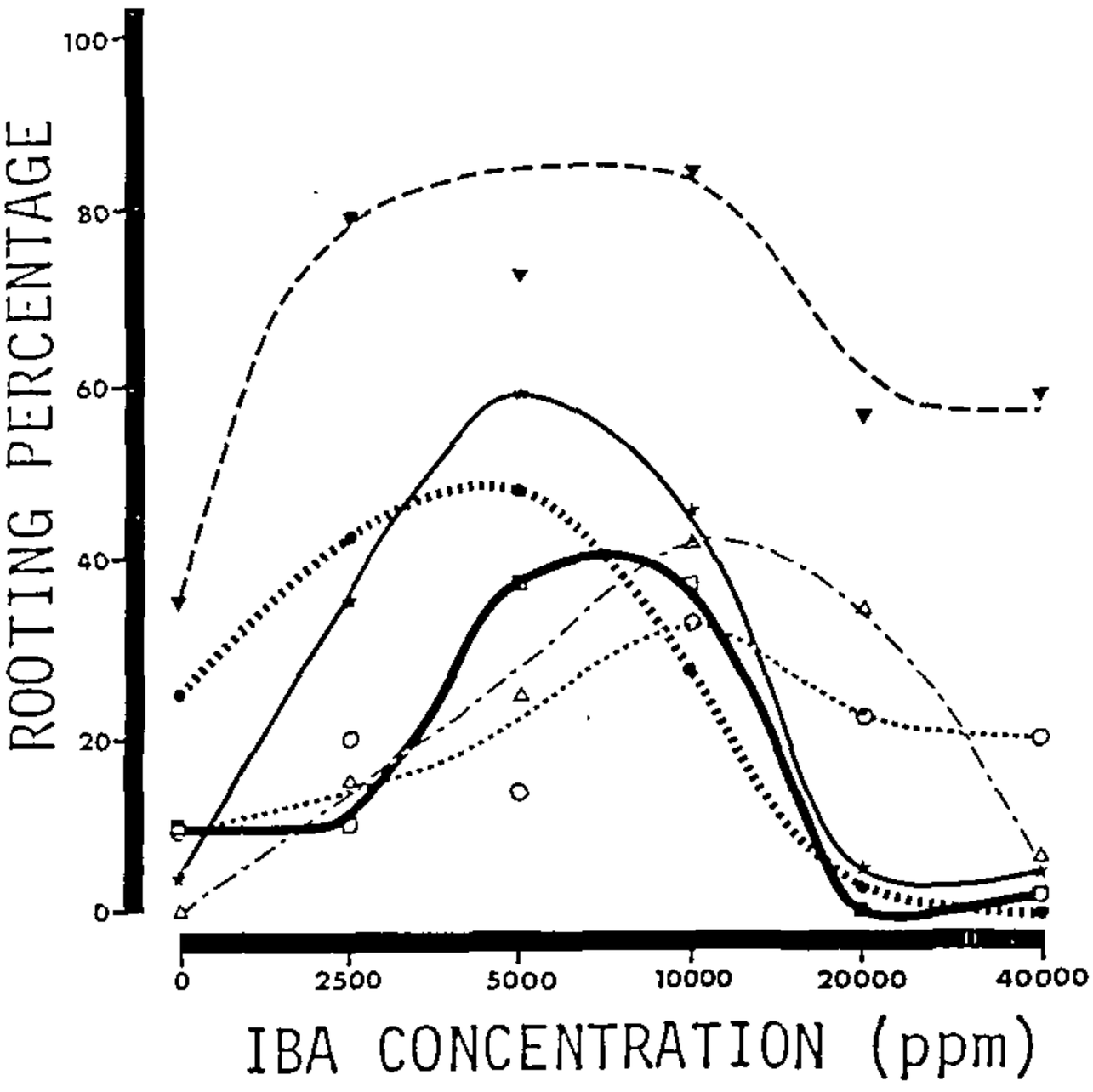

Figure 2. Plants with rooting percentage peaking or plateauing between 5,000 and 10,000 ppm IBA. LSD (P = 0.05): *Chaemomeles speciosa* 'Rubra' (▼), 19%; *Prunus domestica* 'Verity' (○), 20%; *Acer platanoides* 'Crimson King' (△), 18%; *Malus* 'Royalty' (★), 18%; *Tilia* × *europaea* 'Pallida' (□), 16%; *Betula pendula* 'Gracilis' (●), 19%.

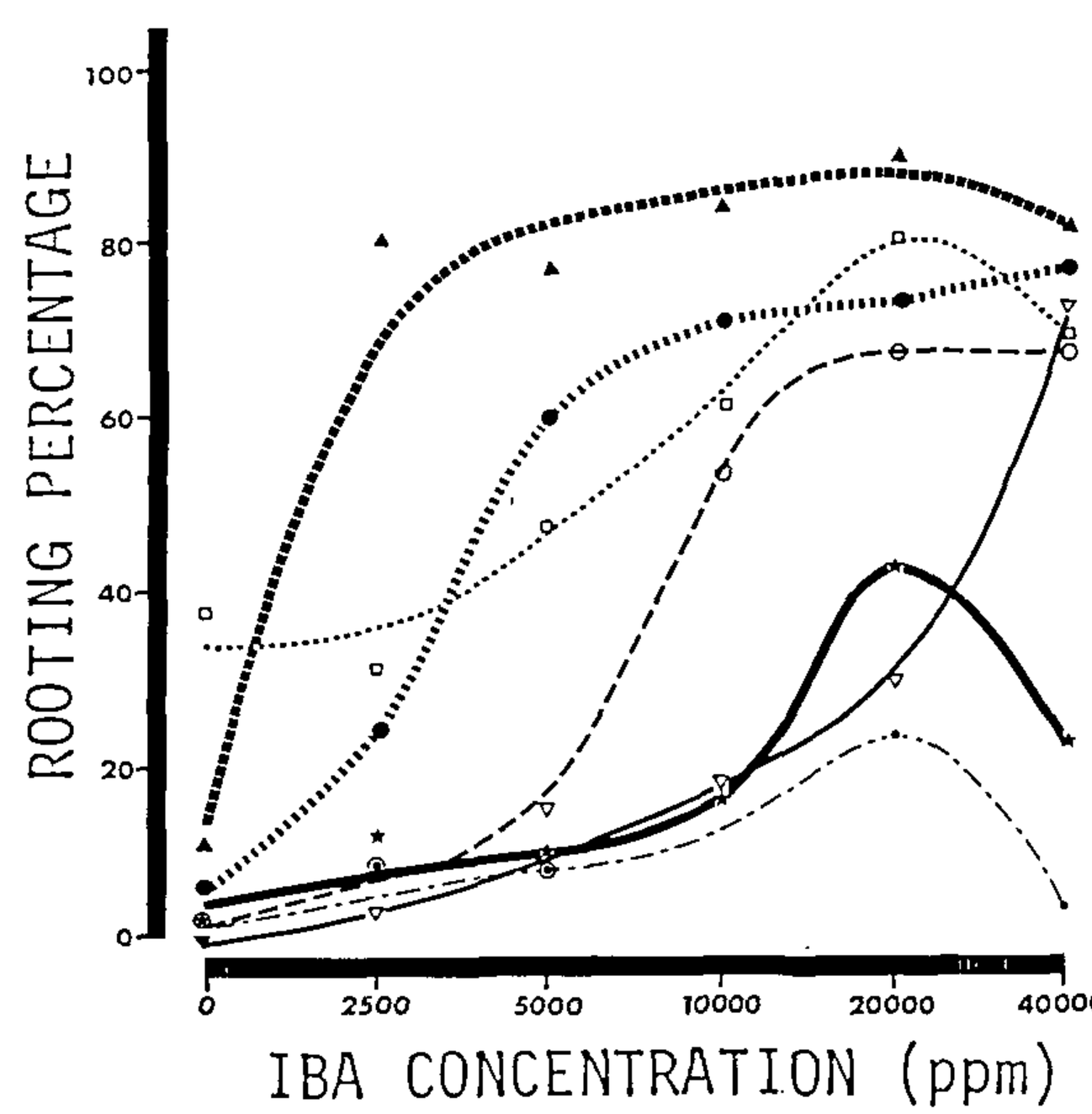

Figure 3. Plants with rooting percentage peaking or plateauing between 20,000 and 40,000 ppm IBA. LSD (P = 0.05): *Prunus triloba* 'Multiplex' (▲), 15%; *Magnolia stellata* (●), 25%; *Amelanchier laevis* (▽), 22%; *Elaeagnus angustifolia* (□), 18%; *Sorbus alnifolia* (○), 21%; Prunus domestica 'Stanley' (★), 17%; *Prunus domestica* 'Valor' (●), 11%.

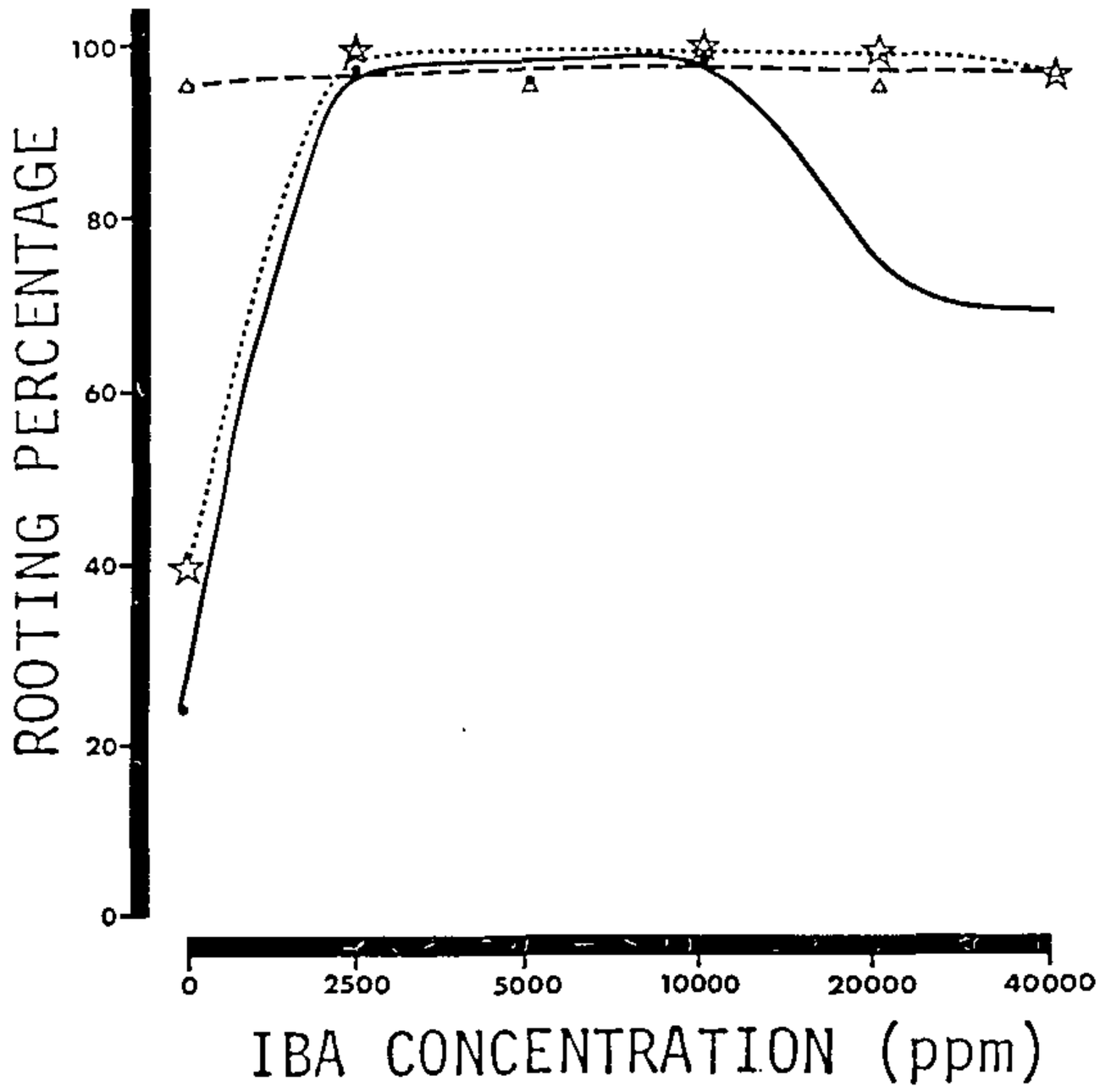

Figure 4. Rooting percentage of three easily-rooted shrubs in response to IBA concentrations. LSD (P = 0.05): *Prunus* × *cistena* (☆), 6%; *Forsythia* × *intermedia* 'Lynwood Gold' (△), not significant; Euonymus alata 'Compacta' (●), 16%.

While auxins have been distinctly beneficial for promoting rooting in many plant species, their effects also have been variable, inhibitory, and sometimes detrimental to certain species (5,7). Brown and Dirr (3) and Burd and Dirr (4) reported that high concentrations of IBA between 20,000 and 30,000 ppm often resulted in defoliation, significant injury or death in crabapple cuttings. Thus, the occurrence of significant defoliation in cuttings of the three cultivars of *Prunus domestica* (Figures 2 and 3), and also the relatively late date of cutting insertion of these cultivars, may account largely for their poor rooting. Low rooting response of other species such as *Quercus rubra* (Figure 1), *Betula pendula* 'Gracilis', *Tilia* × *europeae* 'Pallida', and *Acer platanoides* 'Crimson King' (Figure 2) also may have been associated with factors such as inappropriate time of cutting insertion (9), or to inherent difficulty in propagation (7,8,10,14).

Incidence of basal injury to cuttings as described by Chong (5,6) increased in all plants with increasing IBA concentrations, especially between 20,000 and 40,000 ppm. However, increasing basal injury to plants in Figure 3 was associated with increased swelling and enhanced rooting above the injured (untreated) portion with IBA treatments $\geq$ 20,000 ppm. In contrast, increasing basal damage to plants in Figures 1 and 2 was associated with increasing root inhibition with IBA treatments > 2,500 ppm and > 10,000 ppm,

respectively. While root inhibition of plants in Figures 1 and 2 seemed to be due to IBA phytotoxicity (7), in Figure 3 basal damage seemed to act like a girdle causing carbohydrates to accumulate, resulting in swelling and increased rooting (9).

Dirr (7) indicated that cuttings of some plants will root over a wide range of IBA concentrations. Notwithstanding the occurrence of IBA-induced basal damage also to cuttings of all three easily-rooted shrubs (Figure 4), very high rooting response occurred with IBA treatments between 2,500 and 10,000 ppm for *Euonymus alata* 'Compacta', and between 2,500 and 40,000 ppm for *Prunus* × *cistena* and *Forsythia* × *intermedia* 'Lynwood Gold'. In *Forsythia*, a similar response was observed even in the control treatment without IBA. *Chaenomeles speciosa* 'Rubra' (Figure 2) and *Prunus triloba* 'Multiplex' (Figure 3), the two species with the highest rooting percentages among the species shown in each figure, respectively, also exhibited this characteristic. This apparent association between tolerance to a relatively broad range of IBA-concentrations and high degree of rootability is noteworthy. It is interesting that Stoltz and Hess (12) reported that girdling caused a substantial increase in a rooting cofactor above the girdle in an easily-rooted hibiscus clone.

Evidence suggests that physiologically each step of the rooting process is controlled by a delicate balance of growth hormones, both promotor and inhibitor types, in conjunction with various rooting cofactors and complex enzymes (13,14). In view of the stimulative response of some of the species (Figures 1–4) using different amounts of IBA, it is difficult to conceive that rooting is always controlled by this "delicate" mechanism. Auxin application may be a dominant factor in rooting such species.

This study investigated the rooting of a selected number of deciduous woody species in response to varying IBA concentrations and, as an extension to previous studies (3,4,5,6,8,11), identified other species and their favorable response to high concentrations of IBA.

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VOICE: A question for Rick Wells. What time of year do you do your air-layering?

RICK WELLS: We can do it most anytime of the year in warm climates. We are concentrating on early spring and in the fall, so we are able to can the air layers in early summer before it gets hot, and in late fall before it gets too cold.

RALPH SHUGERT: To Steve Hottovy—you alluded several times in your talk to increasing the caliper of your Japanese maple plants. Could you tell us what you do to increase the caliper of the understock?

STEVE HOTTOVY: By leaving lower branches on the seedlings and by topping back at the beginning of the second season.

PHIL BARKER: Would you speculate as to what materials may be in incompatible species other than the ones you worked with?

CHARLES HEUSER: The cyanide compounds are limited in their distribution. The *Prunus* group has them, as does *Taxus*. You have to look at other compounds in other cases of incompatibility, which I have not done.

DALE KESTER: There are two types of almond cultivars—those that are compatible with Marianna plum rootstock and those that are not. We are in the process now in California of trying to screen these two types using field tests. This biochemical test could provide a great opportunity for speeding up this screening process.

RICHARD CRILEY: With regard to the system you describe, can you put both compatible and incompatible callus into the same culture?

CHARLES HEUSER: One of the problems with prunasin is that it is a secondary product and, in callus cultures, secondary products are not produced in high enough quantities, or not at all. That is one of the problems we would be running into.

FILIBERTO LORETI: A question for Dr. Chong. In your high concentrations of IBA on cuttings you would have a high concentration of alcohol also. Did you try the potassium salt of IBA, which is water soluble, and would not impose the side effect of high alcohol levels?

CALVIN CHONG: No, we did not use K-IBA, but in our water control we did use 95% alcohol, just as we did for the high IBA levels.

ED SHULTZ: Dr. Chong, in your work with IBA at high levels, you did not mention NAA once. In future work could you test combinations of NAA and IBA to see what synergistic effects may appear at high levels of each?

CALVIN CHONG: Yes, I agree, but this is a case of where there is so much work to be done that we need to take it a little at a time. I do plan to do more work with NAA. Right now I am working on studies of liquids and powders applied at the same time.

ANNE KYTE: Dr. Durzan, do I understand that your original explant material is after fertilization and, therefore, not true-to-type for your somatic embryogenesis?

DON DURZAN: There are several origins of this type of tissue that has the embryogenetic potential. There is no doubt that this material represents the new generation rather than the mother tree, but in the material we were working with, both parents were blister-rust resistant. After fertilization the process is enhanced quite a bit. You can get as many embryos as you want.

DORMANCY CONTROL IN MAGNOLIA SEED GERMINATION

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This project was undertaken to elucidate and confirm the pattern of seed dormancy and the conditions required to achieve an optimal germination in a range of the early flowering Asiatic magnolias. It constitutes the primary phase in a series of observations which are being carried out to develop a productive and reliable schedule for magnolia seedling production. The programme is required to produce seedling rootstocks of suitable size, at a relevant season, for budding or grafting with scions of selected clones or named cultivars of the early flowering, "tree" type, Asiatic magnolias.

It is necessary to propagate these plants vegetatively so that flowering specimens can be produced in an acceptable time span. Seedlings of some species (e.g. *Magnolia campbellii*) can exhibit juvenile phases of up to 40 years and even then flower quality is not guaranteed. Stem cutting propagation is not reliably documented and what little information is available points to a poor rooting capacity of the stem material and the slow initial growth rates of rooted cuttings. Thus grafting becomes the only reasonable, commercially acceptable and economic method of propagation, especially in those cases where limited stem material has to be used productively. It is possible that increased supplies of suitable stem material, produced as a result of this exercise, will lead to a study of propagation by stem cuttings.

As would be anticipated, in any grafting exercise, it would be prudent, at least initially, to use seedlings of the same species as a rootstock for a particular scion—or at least a species or a hybrid which is both closely related and of the same vigour and growth pattern. It also seems wise to determine graft compatibilities, scion growth rates and tree performance using a range of rootstocks for each scion cultivar, in the event that seed of any subject became unavailable and the range of rootstocks thus becomes restricted. What evidence is currently available suggests that there is a wide ranging intercompatibility among most temperate species and hybrids in the genus *Magnolia*—whether they are evergreen or deciduous. There is little documented evidence, however, on the subsequent performance of various stock/scion combinations, the only reports being restricted to observations on the need to use stocks and scions of similar girth development and rates of growth. It may also become apparent that certain combinations of stock and scion will induce a more precocious flower production.

Magnolia seeds are produced in a cone-like fruit of coalescent, nominally two-seeded, fleshy follicles. At the time of flowering, pollination and subsequent fertilisation is often erratic so that only a limited number of seeds may develop and a contorted cone is produced. Those seeds which do develop nevertheless normally exhibit good viability. Pollination may be limited by the availability of certain insects and successful fertilisation may be limited by insufficiently warm temperature at the critical period. The seeds are liberated from the cone in the late summer to early fall period. As a result of drying the follicles will split longitudinally along their outer edge and eventually the seeds fall free. In the initial dispersal stage they are retained and hang temporarily from the follicle by a thread-like, mucilagenous "suspensor".

Collection of the seeds is achieved by removing the fruits from the tree just at the stage when the follicles begin to split and the scarlet/orange/red seeds can just be seen. The fruits are then air-dried in a warm, dry environment until the seeds can be shaken free. It is not advisable to remove the fruits from the tree until this stage has been reached, as immature cones may not dehisce satisfactorily. The drying process should not be prolonged beyond the stage that is necessary to achieve separation of the seeds, as excessive drying may lead to a loss of viability in the seed sample.

The seeds are relatively large, and when fresh are fleshy and sticky. Structurally the seed consists of a minute embryo which is embedded in the base of the endosperm and this, in turn, is retained by a thin, skin-like internal seedcoat. This part of the seed is surrounded by an inner hard seedcoat which itself is embedded in a thick, oily, fleshy, outer seedcoat. This outer seedcoat provides the attraction for birds or small rodents and so ensures dispersal. It also protects the seed, in the short term, against desiccation and prevents imbibition. The inner, hard-textured seedcoat protects the seed on its passage through the digestive tract of the animal. Despite the hardness of this seedcoat this factor is not a constraint to imbibition nor conversely does it protect the seed against water loss.

The embryo is immature (i.e. it is differentiated into radicle and plumule but is as yet very small); rarely it is more than one sixth the length of the seed.

The endosperm is large and virtually fills the seed: the food reserve is stored as fats and oils and is consequently very susceptible to inactivation as a result of drying. Long term storage at high temperatures can be deleterious—as a result of the materials becoming rancid.

Observations on the storage of *Magnolia macrophylla* seeds (7) have indicated that the extracted and cleaned seeds can be stored without any significant loss of viability, under water—conserving conditions and at room temperature, for periods of up to 180 days.

This particular study was not an original exercise but was

prompted by the results of trials conducted on *Magnolia virginiana* by Del Tredici (2) of the Arnold Arboretum. His observations had determined the basic pattern of dormancy, its treatment and the conditions necessary to encourage germination for this species. He also reported, from more limited evidence, that very similar patterns were exhibited by other North American species. It was, therefore, necessary to determine whether the Asiatic species behaved in a similar pattern.

The successful seed germination of temperate subjects having seeds with an immature embryo will conventionally depend upon the following sequence—maturation of the embryo, the removal of embryo dormancy controls, and the provision of an environment favouring germination.

The normal expectation is that embryo maturation will be achieved by warm stratification of the imbibed seed, that this should be followed by a period of chilling to overcome the dormancy factors in the matured embryo and then the subsequent exposure of the seed to a sufficiently warm temperature that germination and emergence is encouraged—a sequence that is typically encountered for the immature embryos of *Fraxinus excelsior* and *F. nigra* and the rudimentary embryos of *Ilex opaca* and *I. aquifolium*.

The sequence of treatments which are required to achieve germination in the genus *Magnolia* however is exceptional, and it is not one which is a normally recognised category in the usually proposed systems for the classification of seed dormancy. In the case of magnolias (and certain other *Magnoliaceae*), the embryo requires a period of chilling in order to remove the dormancy controls which are apparently already present and effective in this immature condition (thus preventing embryo maturation) as an initial treatment; subsequent exposure to warm temperature causes the embryo to increase to mature size and as a result of the uninterrupted continuation of this expansion and development the seedcoat ruptures and this leads into emergence (i.e. germination) without delay.

The practicalities involved in the treatment of the seed, in order to encourage controlled germination, begin with the extraction of the seed from its outer fleshy seedcoat. This can most readily be achieved by maceration of the seeds in warm water followed by a short period of fermentation (24 to 48 hrs); subsequent maceration and cleaning in fresh water should provide a reasonably clean sample. A final rinse using a conventional liquid detergent removes any oily film remaining on the surface of the seed. The seed in its bony seedcoat can then be surface dried and is ready for assessment and further treatment. The seed should then be treated without delay (i.e. stored or subjected to its germination pretreatments) to prevent any internal water loss from the imbibed embryo and food reserve.

When required, the seed sample is stratified using a moist

extending medium—at about four volumes of medium to one volume of seed—and is sealed in a suitable container (a thin grade of polythene bag). This labelled container is then refrigerated at 1 to 3°C in order to achieve the chilling effect necessary to overcome the embryo dormancy. The majority of the surveyed literature usually makes vague and blanket recommendations for long periods of stratification in the range of 90 to 180 days. All of the species observed, however, exhibited some radicle emergence on exposure to warmth after 42 days of chilling, with a maximum response being achieved after 56 days; however, emergence was most uniform (i.e. with least variation about the mean) after 63 days of chilling.

Germination (seed leaf emergence) will occur after 32 days at 20°C and 42 days of chilling, although the mean average date of emergence did decline to 28 days with increasing periods of chilling to 84 days. The exposure to warmth causes the embryo to mature until it fills the seed, continued growth ruptures the seedcoat and eventually the seedling emerges.

The accurate determination and application of information of this type permits the development of a simple schedule for the programming and timing of germination. Assuming that the viability of the sample is adequate, it becomes possible to chill and then warm stratify under artificial conditions so that the seeds can be station sown after 90 days (63 days of chilling + 27 days of warm stratification) with the expectation of emergence in 3 to 5 days.

The response of all the Asiatic species, which were the subject of these observations, was remarkably similar to, and corresponded closely with, the results previously reported for the North American species; however the germination response to chilling for periods of less than 42 days was not nearly so marked in the Asiatic species. It would appear that the general schedule described above would prove successful for the following species:

Asiatic	*American*
M. campbellii subsp. *mollicomata*	*M. virginiana*
M. dawsoniana	*M. macrophylla*
M. sprengeri	*M. tripetala*
M. cyclindrica	
M. kobus	
M. × *veitchii*	

It should be emphasised that these observations were made on freshly harvested and extracted seeds and that responses from seeds obtained from commercial sources were usually erratic and unreliable even if viability appeared to be acceptable.

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HORTICULTURAL ROCKWOOL AND DIATOMACEOUS EARTH IN PLANT PRODUCTION SYSTEMS

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Containerised plants were traditionally propagated and grown in soil-based media but there has been a major shift towards soilless media in the last 30 years. Peat, sawdust, pinebark, sand, vermiculite, and perlite are all used in a variety of mixes but the search for suitable ingredients continues. This paper deals with developments in the use of horticultural rockwool and diatomaceous earth as components of plant production systems.

HORTICULTURAL ROCKWOOL

This material was developed in Denmark in the late 1960's and has been used increasingly in Europe since the mid-1970's where the major usage is for growing greenhouse vegetables and flowers. Some use is made of rockwool for plant propagation in Europe but usually for plants which are subsequently grown on in a complete rockwool system.

Horticultural rockwool was not released onto the Australian market until 1982 and the material has mainly been used in plant propagation—particularly of Australian native plants—although some rockwool systems for cut flowers have been developed.

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Horticultural rockwool was not released onto the Australian market until 1982 and the material has mainly been used in plant propagation—particularly of Australian native plants—although some rockwool systems for cut flowers have been developed.

Biggs (1) described the manufacture and properties of horticul-

tural rockwool in 1982 and there is now a great deal of Australian industry experience with the material.

Blocks of various sizes are used for propagating a wide range of plants.

Propagation applications. It is important to understand the typical Australian nursery techniques which rockwool could replace. Cuttings are usually propagated under mist in sand-based media in trays or individual propagation tubes. Rooted cuttings are then potted into their final containers.

Initial commercial scale nursery propagation in rockwool was done where propagators were having problems either with striking or potting on. Examples of these were *Grevillea* 'Robyn Gordon' and miniature roses. Root production was very good in horticultural rockwool and losses after potting on were reduced to effectively zero although *Grevillea* 'Robyn Gordon' required careful management of the water content in the blocks.

The propagation of many Australian native plants at first had only mixed success as these plants require a well aerated rooting medium. Rockwool has very different properties from traditional media and requires different management techniques to ensure optimum plant growth. Waterlogging of the propagation blocks can be a real problem if traditional watering strategies are used and taller blocks were introduced to provide a more aerated environment.

Although the initial incentive for using rockwool propagation blocks was to solve problems, some propagators have looked upon the technique as a completely different propagation system and have modified their production systems to accommodate plants propagated in a different way.

It is now almost 4 years since horticultural rockwool was first used in Australian nurseries. Several hundred different plant species have been successfully propagated in a range of block sizes. The range of plants grown extends over flowers, indoor plants, vegetables, trees, shrubs, and Australian natives. Propagation has been initiated from a range of seeds, seedlings, tissue-cultured plantlets, hardwood and softwood cuttings.

Principles for successful use of rockwool for propagation.

- It is important to select the appropriate block size for the subject being propagated.
- Sheets of blocks which are to be moved for potting on should be supported in a seed tray.
- Blocks must be thoroughly wet before use. Complete wetting takes more water than anticipated.
- Rockwool is initially sterile but can easily be contaminated especially with diseases, unless rigorous hygiene measures are used.

- Insert cuttings only as far as necessary for support. Pushing them in too far places the bases of cuttings in a zone of lower air content.
- If liquid feeding is required then a complete feed including trace elements must be used. Normally plants are not fed before they have rooted but if nutrients are required from the start, e.g. with tissue-cultured plantlets, then the pH of the solution used for wetting the blocks should be lowered to counter the initial alkaline reaction. With rooted cuttings that have small roots it is advisable to water with nutrient solution before potting-on so that roots are encouraged to grow out into the potting medium.
- Control the water content (and hence air content) to a suitable percentage for the particular subject. Block height, depth of insertion of the cutting, drainage characteristics of the supporting surface on which the blocks stand, the method and frequency of watering—these all influence the water:air ratio.
- Consider and allow for the influence of the propagation system and environment on the blocks. Australian propagators have used rockwool blocks successfully in closed tents, misted tents, open bench systems, heated and unheated beds. Different systems have different effects on the behaviour of the blocks, e.g. heavy misting can cause disastrous waterlogging while open, heated benches increase evaporative drying.
- Pot up the cuttings as soon as roots emerge from the base of the block. This takes full advantage of the beneficial properties of the material and avoids the problem of roots growing into adjacent blocks. The simplest technique for separation is to split off a long row of blocks from the sheet and then tear off the individual blocks (similar to separating postage stamps.)
- When converting from another propagating medium to rockwool it is vitally important to recognise differences and to allow for them. For example, a recipe for failure would be to push water sensitive cuttings through to the bottom of blocks, place the blocks on a non-draining surface and then apply frequent, heavy mist.

Burton (2) and Donnan and Biggs (3) have reported propagation details for cuttings rooted in rockwool compared with 50:50 peat:perlite mixes while Ellyard, Ollerenshaw and Hadobas (4) have studied the medium specifically with Australian native plants. There is good evidence to suggest that cuttings in rockwool blocks produce roots more rapidly and can be potted at a very early stage.

Cuttings rooted in tubes using traditional flowable media need to produce roots systems sufficient to bind the medium together before they can be potted.

Drawbacks to using rockwool propagating blocks.

- Some cuttings are too large and the propagation blocks split when the cuttings are inserted. Making a larger hole with a dibber stick before inserting the cuttings can help with these subjects.
- Propagating blocks are rarely suitable for holding plants for extended periods once they have rooted. Roots of plants which are fed regularly after rooting will soon grow into adjacent blocks. This makes it difficult to separate plants without tearing roots. Plants held for long periods tend to damp-off. Rockwool provides optimum benefits when cuttings are potted soon after rooting.
- Potting rockwool blocks into well-drained media can cause problems unless the medium is kept moist until roots have grown out into it.

There is probably a greater use in Australia of horticultural rockwool for ornamental plant propagation than anywhere else in the world. It has proved particularly useful in situations where propagators have experienced problems with "difficult-to-root" subjects but there are instances (2) where whole propagation systems have been re-structured following the introduction of rock-wool. There is great potential with the material for the propagation of plants for export to countries where organic based media are unacceptable. Horticultural rockwool is another resource in the tool kit of today's plant propagator.

DIATOMITE

Diatomite is a sedimentary rock which consists of the siliceous skeletal remains of tiny freshwater or marine animals called diatoms. When the animals died the skeletons sank to the sea or freshwater lake floor where very thick deposits gradually accumulated. Geological movements have relocated the deposits into land situations from where the diatomite can be mined. The deposits are up to 100 million years old. The major uses of diatomite are for swimming pool filters, as pet litter, as a carrier for pesticides, in dust formulations, and as an absorbent to soak up oil and other chemical spillages.

There is a large diatomite deposit at Barraba in northern New South Wales, Australia, and recent research has been directed at determining the suitability of the material when used in seedling and potting mixes. Trials compared the performance of diatomite as mined (raw ore fines) with calcined material produced by passing the raw ore fines through a coal-fired rotary kiln.

Seedling trials. Mixes with varying percentages of diatomite (two grades), peat, and vermiculite were compared with a 50:50 peat:vermiculite control for the germination and early growth of tomato and onion seeds. No significant differences were detected between seedling emergence and growth in any of the mixes. Growth was quite acceptable in mixes containing 50% by volume of either grade of diatomite.

Flowering pot plant trial. Marigolds were used as the test plant in a trial where diatomite was used in the potting mixes in conjunction with peat and vermiculite. Up to 50% of either raw ore fines or calcined diatomite was used in the mixes. Growth of the marigolds was commercially acceptable in all mixes but the best results were obtained in mixes containing the raw ore fines material. This is thought to be due to the fact that the untreated mined diatomite from Barraba contains 30 to 40% clay (kaolinite and halloyrite) which provides cation exchange capacity not exhibited by the calcined product.

Australian natives trial. Four Australian native plants were grown in two commercial potting mixes which were supplemented with 25% and 50% of two grades of diatomite. The plants used were *Callistemon* 'Kings Park Special', *Melaleuca armillaris*, *Grevillea obtusifolia*, and *Grevillea* 'Ivanhoe'.

Most plants grew at least as well in the mixes containing diatomite as in the straight commercial mixes. The exception was *Grevillea* 'Ivanhoe' which reacted extremely unfavourably in mixes containing 50% of the raw ore fines grade of diatomite.

Plant growth was best in mixes which contained calcined diatomite. The large calcined particles remained discrete throughout the trial and improved the drainage and aeration characteristics of the mixes. The raw ore fines product with the high clay fraction reduced water infiltration rate, drainage, and aeration.

Table 1. Plant height (cm) 6 months after potting.

	Mix 1					Mix 2				
	Neat	25% diatomite		50% diatomite		Neat	25% diatomite		50% diatomite	
Plant		calc[1]	rof[2]	calc[1]	rof[2]		calc[1]	rof[2]	calc[1]	rof[2]
Callistemon 'Kings Park Special'	39.50	62.00	57.00	67.00	49.00	71.00	67.00	60.00	72.00	64.00
Melaleuca armillaris	69.50	95.00	88.00	97.00	84.00	105.50	105.00	97.00	111.00	92.00
Grevillea 'Ivanhoe'	77.00	87.00	79.00	87.00	43.00	87.50	79.00	64.00	86.00	45.00
Grevillea obtusifolia	—	—	—	—	—	—	—	—	—	—

[1]Calcined diatomite
[2]Raw ore fines

Plant heights and dry weights 6 months after potting tube stock into the mixes are shown in Tables 1 and 2.

Results with Australian freshwater deposits of diatomite indicate that it can be incorporated up to 50% by volume into seedling and potting mixes. Vegetable seedlings and flowering marigolds performed well in all mixes but specific responses were detected with Australian natives. Further trials are being undertaken to see if preferential patterns can be determined.

Table 2. Shoot dry weight (g) 6 months after potting.

	Mix 1					Mix 2				
	Neat	25% diatomite		50% diatomite		Neat	25% diatomite		50% diatomite	
Plant		calc[1]	rof[2]	calc[1]	rof[2]		calc[1]	rof[2]	calc[1]	rof[2]
Callistemon 'King Park Special'	17.40	33.20	30.13	36.90	28.90	31.23	32.28	24.38	40.23	33.10
Melaleuca armillaris	30.90	51.13	37.98	57.08	42.50	46.26	54.03	42.58	50.36	39.65
Grevillea 'Ivanhoe'	38.44	48.70	42.76	58.35	10.50	41.75	46.83	47.95	49.16	16.30
Grevillea obtusifolia	19.78	25.68	24.00	27.98	25.73	24.00	25.95	21.45	17.50	died

[1]Calcined diatomite
[2]Raw ore fines

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THE EFFECT OF PROPAGATION METHOD ON FORCED POTTED PLANTS AND ON PATHOGEN RESISTANCE IN *SYRINGA VULGARIS*

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Abstract. Production of *Syringa vulgaris* as forced potted plants is significantly affected by the cultivar and its method of propagation. Few flower buds were set on one-year-old plants from tissue culture and none were set on one-year-old plants from cuttings. Plants from tissue culture were significantly taller and wider than plants from cuttings. Scanning electron microscopy revealed fewer stomates on plants from tissue culture. A count of stomates per unit area of leaf indicated 21 to 32% more stomates on plants from cuttings. Damage from *Pseudomonas syringae* was greater in *S. vulgaris* 'Mme. Lemoine' than in 'Michael Buchner,' and greater in plants from cuttings than in plants from tissue culture.

REVIEW OF LITERATURE

Lilac sprays have been produced for sale in Europe for over 200 years by forcing large bushes and cutting their flowering branches (1). McKelvey authored a thorough review of the European lilac industry in 1928 (2). Although there has been heightened interest in lilac sprays since about 1970, their high price and short vase life of 3 days limits demand (1).

Much research has recently been done to extend the vase life of cut lilac sprays by adding nutrient solutions and phenol inhibitors to the vase water (3,4). Vase life has been increased from 3 days to 10 days with these methods (3). However, potted plants of *S. vulgaris* 'Michael Buchner' have been known to bloom for up to 3 weeks at Oregon State University.

Potted lilac plants have been produced in Europe and the U.S. for forced flowering (6). After 1919, when Quarantine 37 was enacted, all importation of European lilac plants was stopped (5).

Flowering potted lilac plants were produced in the U.S. until 1940 (6). At this time, lilac plants were produced by budding or grafting. These plants took 3 years to produce well-branched flowering plants, which were then too large for the average home (7). Improved methods for rooting lilac cuttings have reduced the time to produce flowering plants (11,12,13,14). Production of large numbers of lilac plants throughout the year is now possible using tissue culture (8,9,10). At the North Willamette Experiment Station (NWES), Aurora, Oregon, lilac plants from tissue culture grew faster and flowered at a younger age than lilac plants from rooted cuttings.

One of the difficulties in growing lilac plants has been a blight caused by *Pseudomonas syringae*. Cultivars in the Pacific Northwest have shown a wide range of damage believed to be caused by this pathogen (19).

MATERIALS AND METHODS

Lilac plants grown from cuttings (Wedge Nursery, Minnesota) and from tissue culture (Briggs Nursery, Olympia, Washington) arrived in February and April, 1985, at the NWES. Tissue culture plants from 2-in. pots and bare root cutting plants were potted into 6-in. pots using a fertilized 90% conifer bark and 10% sand mix. These plants were grown in a heated polyethylene covered hoop house at a temperature range of 50–70°F with lighting from 10 pm to 4 am until April 15. These plants were moved outside on April 20 and were fertilized with Osmocote 18-6-12. Water was applied by overhead irrigation. These plants remained in the nursery, unprotected throughout the winter of 1985.

The lilac plants were arranged in a randomized block design. Variables tested were propagation method, i.e., either tissue culture or rooted cuttings, and lilac cultivar, i.e., either 'Mme. Lemoine' or 'Michael Buchner.' Each of four treatments had 5 replications of 5 plants.

Treatments were evaluated by counting the number of branches and flower buds on each plant, and measuring plant height (cm) and width (cm). These results were recorded on December 9, 1985.

All lilac plants in each treatment showed various degrees of damage from a naturally occuring infection, probably caused by *Pseudomonas syringae*. Diseased leaf segments were macerated in test tubes with 5 to 10 ml of sterilized distilled water. The suspension of plant tissue was inoculated onto petri plates containing Kings B media (15). After 36 to 48 hours, fluorescent colonies were observed. These colonies were tested for their reaction to an oxidizing reagent (16), and it was concluded that the damage was, indeed caused by *P. syringae*.

One lilac leaf from each treatment was observed with a scanning electron microscope on June 10, 1986. Initial observation indicated a difference in the profusion of stomates on the underside of leaves from different treatments. On July 20, 1986, ten replicas of the undersides of leaves were made for each of the 4 treatments (17). Each replica was then transferred onto a piece of clear tape which was mounted on a glass slide. Photographs of the 40 replicas were made using a dissecting microscope equipped with a camera. The number of stomates per 0.5 mm^2 was counted. Within each of the 4 treatments, the numbers of stomates per photograph were averaged (Table 1).

Table 1. *Mean number of stomates*[1] *on two cultivars of Syringa vulgaris from two propagation methods*[2]

Cultivars	Propagation methods	
	Tissue culture	Cuttings
Mme. Lemoine	47.4	69.7
Michael Buchner	55.7	70.6

[1]per 0.5 mm^2.
[2]10 leaf samples per treatment.

RESULTS

Statistical analysis of the number of branches, plant height and width of potted lilac plants indicates that the cultivar and method of propagation have a significant affect on the production of lilac plants for flowering potted plants.

No significant difference because of propagation method was observed in the number of branches for *S. vulgaris* 'Mme. Lemoine. Plants from tissue culture had a mean of 6.0 branches per plant and plants from rooted cuttings had a mean of 6.32 branches per plant. However, *S. vulgaris* 'Michael Buchner' had significantly more branches when propagated by tissue culture. Plants from tissue culture had 11.92 branches per plant and plants from rooted cuttings had 3.45 branches per plant (Table 2). Branches on plants from rooted cuttings were less vigorous and narrower in diameter.

Table 2. Mean number of branches on two cultivars of *Syringa vulgaris* from two propagation methods.[1]

Cultivars*	Propagation methods*	
	Tissue culture	Cuttings
Mme. Lemoine	6.00	6.32
Michael Buchner	11.92	3.45

[1]25 plants per treatment.
*Significantly different at probability 0.01.

The average width of lilac potted plants was significantly different because of propagation method, but not because of cultivar. The mean width of *S. vulgaris* 'Mme. Lemoine' from tissue culture was 13.66 cm, and from rooted cuttings was 8.36 cm. The mean width of *S. vulgaris* 'Michael Buchner' from tissue culture was 13.94 cm, and from rooted cuttings was 7.00 cm (Table 3).

Table 3. Mean width of two *Syringa vulgaris* cultivars from two propagation methods[1].

Cultivars	Propagation methods*	
	Tissue culture	Cuttings
Mme. Lemoine	13.66 cm.	8.36
Michael Buchner	13.94	7.00

[1]25 plants per treatment.
*Significantly different at probability 0.01.

The height of lilac potted plants was significantly different because of propagation method, but not because of cultivar. The mean height of *S. vulgaris* 'Mme. Lemoine' from tissue culture was 36.70 cm, and 16.64 cm from rooted cuttings. The mean height of *S. vulgaris* 'Michael Buchner' from tissue culture was 41.22 cm, and 16.12 cm from rooted cuttings (Table 4).

Both lilac cultivars and lilacs from each propagation method were microscopically observed for anatomical differences that may be associated with the degree of damage caused by *Pseudomonas*

syringae. The mean number of stomates per 0.5 mm^2 leaf area from tissue culture plants of *S. vulgaris* 'Mme. Lemoine' was 47.4, and from plants grown from rooted cuttings was 69.7 or 32% more stomates on cutting-grown plants. The mean number of stomates per 0.5 mm^2 leaf area from tissue culture plants of *S. vulgaris* 'Michael Buchner' was 55.7 and from plants from rooted cuttings was 70.6 or 21% more stomates on cutting-grown plants (Table 1).

Table 4. Mean height of two *Syringa vulgaris* cultivars from two propagation methods[1].

Cultivars	Propagation methods*	
	Tissue culture	Cuttings
Mme. Lemoine	36.70 cm.	16.64
Michael Buchner	41.22	16.12

[1]25 plants per treatment.
*Significantly different at probability 0.01.

DISCUSSION

After one year at the NWES, taller and wider plants with more branches were produced from lilac plants propagated by tissue culture than from rooted cuttings.

The significant difference in number of branches between *S. vulgaris* 'Michael Buchner' and *S. vulgaris* 'Mme. Lemoine' indicates that some cultivars branch more profusely, which may make them more attractive plants for commercial production of forced flowering potted plants. Also, plants from tissue culture had significantly more branches than plants from rooted cuttings in *S. vulgaris* 'Michael Buchner' (Table 2). This suggests that propagation method would be important for production of flowering lilac potplants.

The height and width of both lilac cultivars evaluated were significantly greater on plants from tissue culture (Tables 3 and 4). Both cultivars were of similar height and width when propagated by the same method.

More flowers on a forced potted lilac would make it more attractive for commercial purposes, but plant size and branching habit affect flowering. At the NWES, flowering occurred only on plants with very vigorous stems. Lilac plants with many stems of little vigor did not form flower buds. Lilac plants with 5 to 10 vigorous branches were most likely to flower. Only lilac plants from tissue culture were sufficiently vigorous to produce flower buds after one year from propagation.

After 2 years, these same plants from tissue culture produced many flower buds, but were too tall for commercial forced potted plants. After two years, many lilac plants from rooted cuttings have not formed flower buds and are still very small.

Research at the NWES is now being conducted using the

growth regulators, succinic acid-2, 2-dimethyl hydrazide (B-Nine) and (2-chloroethyl) trimethylammonium chloride (Cycocel). These chemicals will be evaluated to determine whether treated plants will be shorter and produce more flowers on a more compact plant after 2 years of growth (18).

The pathogen, *Pseudomonas syringae*, may impede the commercial production of lilac plants as forced potted plants. At the NWES, the degree of damage to lilac plants from this pathogen varied depending on the cultivar and its method of propagation. All lilac cultivars propagated from rooted cuttings suffered more damage than the same cultivar from tissue culture. *S. vulgaris* 'Mme. Lemoine' suffered more damage than *S. vulgaris* 'Michael Buchner.' At least one source has indicated that some lilac cultivars are less susceptible to *P. syringae* (19).

P. syringae enters plant tissue through stomates and cracks in the plant's cuticle (20). Although in our trials there were 21 to 32% less stomates on plants from tissue culture, it is not known whether the number of stomates generally has a role in the extent of infection and damage from *P. syringae*.

Further trials are needed to investigate several other interesting questions. These include whether all lilac plants from tissue culture have less stomates than those from rooted cuttings, and whether stomatic proliferation is influenced by environmental or somaclonal variation (21).

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DWARF CONIFERS FROM WITCHES'-BROOMS

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The project I have been working on at the University of Connecticut is the development of new forms of dwarf conifers. The dwarf plants that I have developed are not the result of hybridization, but originate from seed obtained from mutations found on various conifers. These mutations, called witches'-brooms, occasionally produce seed which give forth plants of which half are dwarf and half are normal.

We have at our nursery over 20,000 plants that range from two to 22 years of age. Although a graft taken from a broom would provide a dwarf plant, I prefer to collect seed because of the variability that occurs among the dwarf seedlings.

We have found that not only do the individual seedlings within a progeny exhibit variability, but differences also occur among progenies obtained from different brooms. Seedlings obtained from two red pine (*Pinus resinosa*) witches'-brooms, for example, have exhibited two different forms of growth.

In one, the plants are all upright while in the other, the branches are horizontal. We are, therefore, on the constant alert for new

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We have found that not only do the individual seedlings within a progeny exhibit variability, but differences also occur among progenies obtained from different brooms. Seedlings obtained from two red pine (*Pinus resinosa*) witches'-brooms, for example, have exhibited two different forms of growth.

In one, the plants are all upright while in the other, the branches are horizontal. We are, therefore, on the constant alert for new

sources of brooms with the hope that they would provide seedlings with even more variability.

We regularly evaluate all groups of seedlings and select those few having the greatest potential for developing into unique plants.

We are currently growing and evaluating seedlings obtained from *Larix laricina, Picea abies, Tsuga canadensis, Pinus banksiana, P. densiflora, P. rigida, P. resinosa, P. strobus,* and *P. sylvestris.*

We also compare the ease in rooting among the select seedlings. Our objectives are to select and name those seedlings that are relatively easy to root. Unfortunately the good rooting clones are not always the most interesting ones.

Once we have named and introduced a new plant, we send cuttings or scions to cooperating growers for them to propagate and grow on.

We have found, in general, that the factors affecting rooting of dwarf conifers are similar to those that influence rooting of most difficult-to-root species, i.e.:

1. Young or juvenile plants root more easily than older or mature plants.
2. Clonal differences, in the ease of rooting, occur among seedlings.
3. The stage of plant development or the time of the year may influence the degree of rooting.

We recently compared the rooting of cuttings taken from two select groups of Norway spruce (*Picea abies* (L.) Karst) witches'-broom seedlings: the 'West Street' clone, seven years old, and the 'Spt-Ldy' clone, 8 years old. Ten cuttings each were taken on January 9, 1986 and dipped into talcum powder containing 1000 ppm indolebutyric acid. The needles at the base of the cuttings were left intact. All cuttings were stuck into flats containing equal parts of peatmoss and sand and placed under a mist system. Rooting results were measured on June 11, 1986 (Tables 1 and 2).

Rooting among the 'Spt-Ldy' cuttings (Table 2) was generally high, over 80%, for all clones, whereas rooting among the 'West Street' clone varied from 10 to 100%.

Another test was carried out with two different Canadian hemlock (*Tsuga canadensis* (L.) Carr.) witches'-broom progenies on January 9, 1986 (Table 3 and Table 4). Ten cuttings each were taken from five different 'Hills' witches'-broom seedlings which were eight years old and from nine different seven year old 'Woodstock' witches'-broom seedlings. The cuttings were given a 3 sec. dip into a solution containing 20,000 ppm IBA in 50% alcohol, stuck into flats of peatmoss/perlite 1:1, and placed under a mist system.

Rooting results were taken on June 11, 1986.

Table 1. Clonal differences in rooting cuttings[1] taken from Norway spruce witches'-broom seedlings.

West St.[2] Clone No.	Percent of cuttings rooted	Average root length	Average number of roots per rooted cutting
3	80	7.9 cm	9.0
6	60	6.1	3.2
43	90	9.7	7.2
64	40	1.4	4.5
135	100	10.2	6.2
143	90	9.0	6.2
144	100	1.5	14.5
155	10	3.4	6.0
205	100	8.8	7.2

[1]10 cuttings per treatment
[2]seven year old plants

Rooting was variable, with some clones (135, 144 and 205) rooting 100%, while others exhibited a poor response (clones 87 and 155), rooting as low as 10 percent.

Table 2. Clonal differences in rooting of cuttings[1] taken from Norway spruce witches'-broom seedlings.

Spt-Ldy[2] Clone No.	Percent of cuttings rooted	Average root length	Average number of roots per rooted cutting
1	100	9.2 cm	13.4
2	80	8.1	9.2
3	80	5.6	5.3
4	90	7.8	6.8

[1]10 cuttings per treatment
[2]eight year old plants

Table 3. Clonal differences in rooting of cuttings[1] taken from Canadian hemlock witches'-broom seedlings.

Woodstock[2] Clone No.	Percent of cuttings rooted	Average root length	Average number of roots per rooted cutting
1	0	—	—
4	70	0.5 cm	2.0
8	60	5.0	18.2
12	100	1.5	8.2
13	100	35.3	9.6
25	90	2.5	25.0
66	50	7.5	2.0
70	80	23.0	2.5
229	90	21.0	2.0

[1]10 cuttings per treatment
[2]all clones were 15 years old

Table 4. Clonal differences in rooting of cuttings[1] taken from Canadian hemlock witches'-broom seedlings.

Hills[2] Clone No.	Percent of cuttings rooted	Average root length	Average number of roots per rooted cutting
0	70	6.0 cm	0.5
11	100	6.5	37.9
16	100	7.0	27.9
17	100	7.5	38.5
21	90	8.0	41.2

[1]10 cuttings per treatment
[2]all clones were 10 years old

With the exception of clone No. 0 all cuttings from the 'Hills' progeny rooted at 90 percent or greater and had large numbers of roots per cutting.

Considerable variability occurred, however, among the nine 'Woodstock' clones. Two clones had 20% and 0% while three clones exhibited over 90% rooting.

The following plants have already been named and introduced to the nursery trade from the University of Connecticut:

Pinus strobus 'Sea Urchin'—is a true miniature shrub. It has very small needles, 3 cm long. After 10 years of growth it has developed into a low mound having a height of only 35 cm and a width of 55 cm. The foliage has a bluish-green appearance.

P. strobus 'U Conn'—is relatively fast-growing compared to other dwarf evergreens, and is currently producing approximately 38 cm of stem growth annually. It has grown to a height of three meters and has a diameter of 2.6 meters in 12 years. The needles are bright green and are approximately five cm long. It is the largest of the dwarf plants named. Its form changes with time from pyramidal to flat-topped.

P. strobus 'Blue Shag'—is moderately fast growing and remains very dense. Growth is mainly lateral; resulting in a plant almost twice as broad as tall. The needles are a bright blue-green. The overall dimensions, after eight years growth, are 0.9 m tall and 1.6 m wide.

P. strobus 'Green Shadow'*—is a multi-trunk, dwarf shrub with a rounded top and with dark green foliage. It has grown to a height of 3 m in 20 years. Its form is broad when young and becomes more tree-like with age. The needles are 7.5 cm long, and thicker than other cultivars.

P. strobus 'Blue Jay'—is a dense low mound which is approximately twice as wide as high. After 10 years, it has reached a height of 0.5 m and a width of slightly more than 1.3 m. The foliage has a distinct bluish cast.

P. strobus 'Soft Touch'—is a dense flattened mound. The needles are relatively short and thin and have a slight twist. It has grown 0.6 m high and 1.2 m across in 8 years.

P. strobus 'Golden Candles'—is an upright shrub with moderately dense branching. Both the candles and the current years foliage have a bright golden color. Grafts of Golden Candles have grown 2.0 m tall and 1.5 m across in 8 years.

P. resinosa 'Sandcastle'—is a dwarf and very dense upright shrub with tufts of short deep-green needles. It has reached a height of 1.8 m and a width of 1.8 m after 15 years growth.

P. resinosa 'Thunderhead'—is a broad low shrub having very long dark green needles. Its branches are loosely arranged. After 15 years it has attained a height of 1.0 m and a width of 2.0m.

Larix decidua 'Varied Directions'[1]—is a relatively fast-growing larch that sends out vigorous branches that reach out in various directions. Its lateral branches are pendulous while its major branches tend to curve upwards. Its lateral growth is approximately 0.5 m per year.

Tsuga canadensis 'Florence'—is a low broad shrub with branches that spread horizontally and are layered. Its branch tips tend to curve down slightly. Its size, after 15 years, is 0.6 high and 1.8 m wide.

Sciadopitys verticillata 'Wintergreen'[1]—is a beautiful deep green cultivar that does not turn bronze during the winters we experience in New England. Its growth rate is relatively fast and, in addition, it roots easily from cuttings. Its growth under our conditions is approximately 30 cm per year and reaches a height of 2 m in 10 years from a rooted cutting.

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[1] not of witches'-broom origin

Figure 1 shows a witches'-broom occurring on a mature white pine tree. Figures 2 through 4 show plants derived from witches'-brooms.

Figure 1. A white pine witches'-broom photographed in Maine.

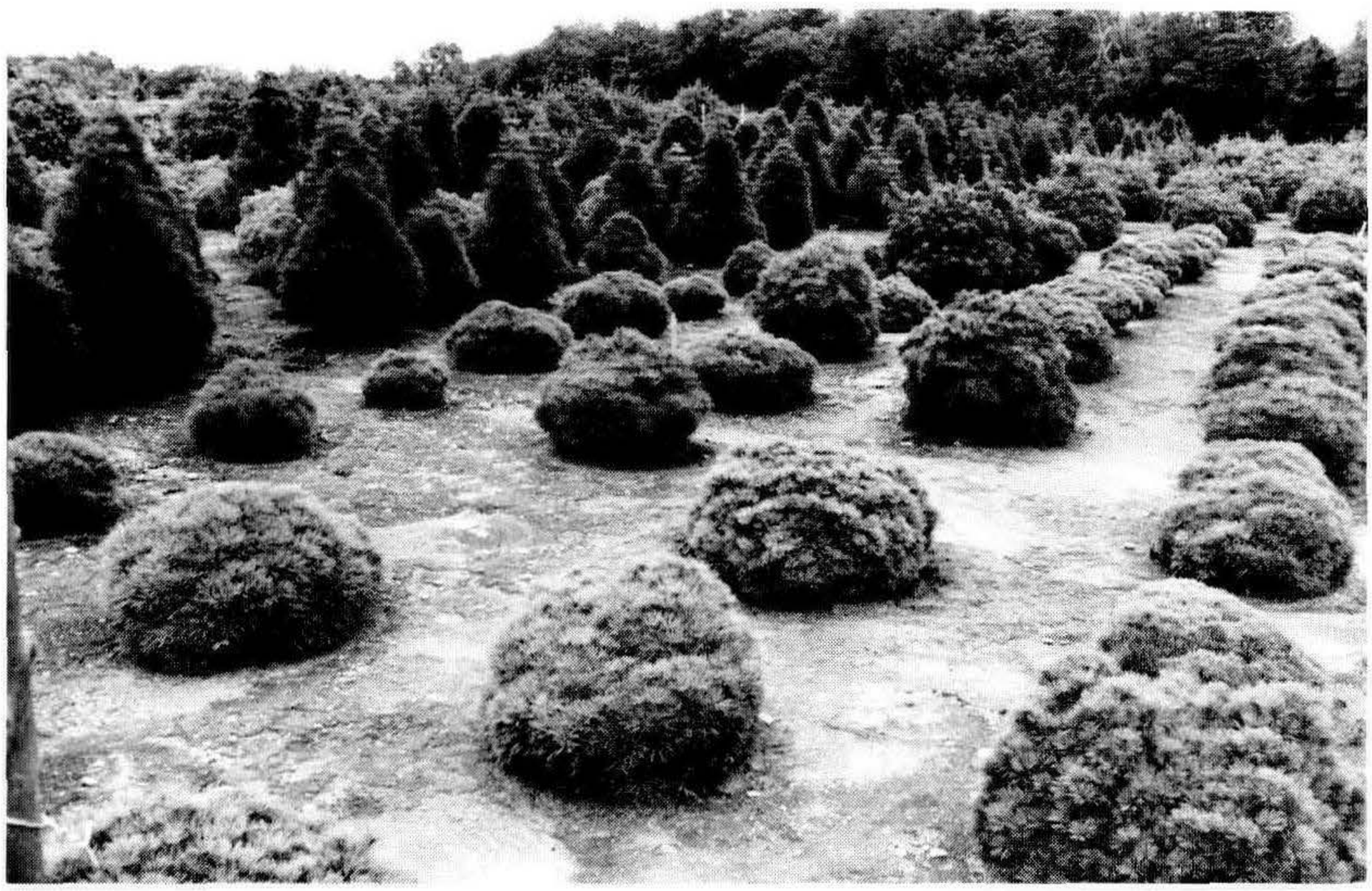

Figure 2. A grouping of 13-year-old white pine witches'-broom seedlings. Japanese umbrella pines in the background. University of Connecticut Horticulture Research Farm.

Figure 3. *Pinus strobus* 'Golden Candles'—a golden yellow white pine seedling selection collected from a witches'-broom.

Figure 4. *Tsuga canadensis* (Hills progeny). A dwarf seedling obtained from a Canadian hemlock witches'-broom.

PLANT SELECTION AND INTRODUCTION— SOME FACTS OF LIFE

H. B. TUKEY, JR.

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When people are asked what they expect from arboreta and botanical gardens they all agree on one thing—to see plants. Nurserymen are no different. They look to botanical gardens for new plants, plants from other regions, and unusual plants with unusual characteristics not found in the trade, because botanical gardens are associated with plant exploration, selection, and introduction.

Where do horticulturists get new plants? Fruit production is based on a small number of cultivars, developed over long periods of time, usually from a chance seedling or a sport. Only in the past 40 years have organized breeding programs begun to produce new and improved cultivars for commercial production, supplanting the better known and older types.

In contrast, vegetable, flower, and turfgrass cultivars have been developed through extensive breeding programs of institutions and commercial companies. Competition is keen, the market is large, and the financial return for success can be substantial. Introductions from the wild, although of interest to plant breeders, seldom find their way directly into the competitive arena of new cultivars, unlike the situation with fruit species.

In the nursery trade, most of the plants we see in catalogues have been grown for years; sometimes a superior form is found by a nurseryman and introduced as a new cultivar. But often, our landscape plants are chance strains, found by good horticultural observers, rather than the product of careful plant breeding or exploration. Of course, there are many exceptions as, for example, the famous 'Bradford' pear from China and the successful breeding programs of roses, rhododendrons, camellias, and hollies.

There are other differences between the development of landscape plants and other horticultural crops. In the case of fruits, vegetables, flowers, and turfgrass, plant explorers now look for genetic materials useful in breeding schemes. In the case of landscape plants, it is the plant itself as a new individual which is collected by the plant explorer and introduced directly to the trade. Another difference is quantity. Most horticultural industries are based on large numbers of a few cultivars. New vegetables and flowers are suggested, even imposed, by the commercial breeding organizations. In contrast, landscape horticulture utilizes hundreds, even thousands, of genera, species, cultivars, forms, and

clones. The industry does no direct selection; rather, it is the buying public, including landscape designers, which determines plants to be introduced and grown on.

Many groups and organizations have been involved actively in landscape plant selection and introduction. The U.S. federal government has introduction and quarantine stations throughout the country and federal agencies, including the U.S. National Arboretum in Washington, D.C. have introduced plants. Many botanical gardens and universities have had success. On the West Coast, the program of the University of British Columbia Botanical Garden at Vancouver, B.C. has received much deserved attention for its involvement of nurserymen and landscape architects in its selection program. Similarly, there are many other countries with trial gardens and introduction programs as, for example, at Boskoop in the Netherlands and at East Malling in England. Commercial nurserymen are always on the lookout for promising plants, and occasionally new strains become popular. More recently, some nursery firms have established formal programs of plant testing and introduction with great potential for the future as, for example, Schmidt and Sons in Oregon and the Weyerhaeuser Corporation in Washington State.

Today there is a resurgence of interest in plant exploration and introduction, due to a number of factors. First, China has been reopened to foreign visitors, and the lure of one of the great depositories of plant material and the memories of plant explorations of the last century have generated great interest. The Chinese have recognized their own natural resources and are working to identify, exhibit, and exploit their own flora.

Second, the environmental movement and concerns about ecology and food production has awakened concerns about the diversity of gene pools for future plants. The U.S. federal government and international agencies have developed sophisticated networks of species collection and preservation, of which the United States system of repositories for important germplasm is an example.

Third, the public has become aware of endangered species, both animal and plant, and the phrase has become a modern rallying cry for individuals and organizations. Finally, Americans are becoming more sophisticated horticulturists. There is increased attention to horticultural education, Master Gardeners, public plantings, edible landscapes, and the therapy of gardening.

All of this has encouraged interests in plants, particularly plants for landscape purposes. Plant explorations, both professional and amateur are the order of the day, so much so that public gardens have found that plant collecting treks can be an important source of funds. At the same time as this resurgence of interest in plant exploration and introduction has occurred, economic support

for universities and other agencies has been seriously eroded. Botanical gardens, never over-funded, have been hard hit by the economy. So when nurserymen look to these organizations for new plants, it must be done with a knowledge of the financial facts of life.

As an example, in Seattle, where the greatest diversity of plants can be grown in all of America, and boasting one of the country's most knowledgeable assemblage of horticulturists, there is not an adequate quarantine facility for imported plants despite great local interest in collecting trips and plants from other regions. Requirements for such a program include, first, an isolated location with room for facilities and surrounding space; land costs are high adjacent to most botanical gardens and other agencies which could support a quarantine station. Second, a greenhouse or screenhouse must be built. Third, skilled personnel must be hired—a curator, familiar with plant quarantine regulations, and a maintenance staff. Altogether, the cost of a simple quarantine station could easily reach $100,000 plus land with an annual operating budget of $75,000. At today's interest rates, an endowment of $1,000,000 would be necessary to support the program.

Similarly, a plant introduction scheme is expensive. After the initial costs of land and buildings, there are annual costs of 3 or 4 staff members, and operating costs to support testing and selection perhaps in several locations, expenses of a selection panel, advertising and publicity, propagation, pest management, harvest, storage, and distribution. If such a scheme produces 50,000 plants per year, a premium just to cover operating costs could easily reach $4 per plant, or require an endowment of $3,000,000. Whereas the costs of developing new food crops, bedding plants, roses, rhododendrons, and other high-volume plants can be recovered from sales, most landscape plants are not used in such abundance; and there are thousands of landscape plants, both woody and herbaceous, from which the discriminating gardener can choose.

This points out some facts of life—any successful plant selection and introduction scheme must have organization and must have financial support. It is impossible in almost all cases to carry out such a scheme with most landscape plants based on sales of the plants alone. Of course, this assumes that all costs will be reasonably assigned. In practice, many organizations do not make direct charges for plant introduction but "borrow" from other operations—some greenhouse space from production, computer time from accounting, and some publicity from advertising. Botanical gardens are no exception and, in their eagerness to develop funding and support, sometimes charge less than what it really costs to do the work, sometimes committing resources without charging for them.

These facts of life are not meant to overwhelm, to discourage,

and certainly not to inhibit programs providing new plants. It is important, it is necessary, and for landscape horticulture, it is still essential especially when so few breeding programs are in progress. On the other hand, it is time for nurserymen as well as managers of botanical gardens and other agencies to recognize the potentially enormous costs involved. Without the institutional help that was available in the 1950s and 1960s, and with the requirements that many programs be self-supporting, we must look elsewhere for funds.

Federal and State budgets must continue to provide funds for conservation, breeding, evaluation, selection, and introduction of new plants including landscape plants. Individual donors and foundations must be solicited to provide endowments; the most attractive parts of introduction programs, *i.e.* endangered species, must be oversold to provide for the less attractive parts. The commercial industry, both large corporations and individuals in small businesses must realize that this essential part of horticulture must be supported, and at greatly increased levels. Agriculture, including the nursery industry, has benefited from public-supported research, teaching, and extension programs for more than a century. In the future, agriculture, including the nursery industry, will have to compete for public funds and must make up the short fall through industry support.

In return, those interested and skilled in plant introductions must work cooperatively. Plant exploration must represent many botanical gardens and agencies, and each must pay a share of the cost. Plant discoveries from explorations must be shared widely. Quarantine facilities must be developed regionally. Selection of plants must be organized and speeded up and improved; patents must be observed. The good programs of today must be made better and more efficient.

The introduction of landscape plants has been a mixture of well-planned exploration and introduction, breeding, and chance discovery by a diverse group of nurserymen, plant explorers, breeders, collectors, and skilled hobbyists. Botanical gardens and arboreta have an important role to play. Knowledge of the process, appreciation of the costs, cooperation, and financial support is absolutely essential.

RALPH SHUGERT: Question for McMillan-Browse about *Magnolia kobis*, could you discuss this in regard to seed germination?

PHILIP McMILLAN-BROWSE: I have germinated seeds of this very successfully. It gives a good quality seedling to use as a rootstock. You must not freeze the seed during stratification as it will kill the embryo.

RALPH SHUGERT: Question for Henry Lima. Did you get any of your lilacs to bloom during your tests?

HENRY LIMA: Our experiments were mainly to produce lilacs with buds, but yes, we did have blooms on some cultivars, especially those from tissue culture and in the second year. They can be forced through January and up to March. With cold storage they can be held and forced at any time.

VOICE: What did you use to control *Pseudomonas syringae*, and did you grow your plants in the greenhouse or outdoors?

HENRY LIMA: The lilacs were grown outdoors throughout the winter. For *Pseudomonas* control you can use a copper spray in the fall once the leaves have dropped, also Agrostrep on new growth, once a week, a 1 tbs. per gal. spray, for stopping the blight.

BRUCE MACDONALD: Has anyone here had experience in using Rockwool for propagation?

BRUCE BRIGGS: We tried Rockwool a good many years ago with poor results. The plants seemed to be very weak going into containers. Perhaps it was something we were not doing right.

CURTIS J. ALLEY MERIT AWARD—1986

Presented by Bruce Briggs at the Western Region 1986 Banquet

The 1986 recipient of this Award was born in Missouri, March 16, 1921. He grew up in Kansas and came to California in 1939 to attend a carpenter's apprenticeship program at California Polytechnic Institute, San Luis Obispo. A few months later he enrolled in the Horticulture program and several years later received a B.S. degree.

During World War II he served in the military as a flying staff sergeant. Then he returned to California Polytechnic Institute as a teaching assistant and became a permanent instructor in 1947. In 1954 he became Acting Department Head of Horticulture. At about that time he took a sabbatical leave to obtain an M.S. degree at Ohio State University. He took another sabbatical leave in 1963 to complete his Ph. D. degree at Ohio State University. Our recipient was a charter member of the IPPS Western Region and active during its formative years. He was the 6th president of the Western Region in 1965–66.

He has been recognised for his many contributions to ornamental horticulture. He has been particularly outstanding as a teacher and is well known for being a good friend of students. He has received numerous awards for outstanding teaching, including ones from the California Nurserymen's Association, the American Florist's Association, American Association of Nurserymen, the Chadwick Award, and the Burt Kallman Award. Our Awardee has

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been instrumental in the development of several student scholarships that annually grant about $100,000 per year. He became Dean of the School of Agriculture at California Polytechnic University in 1974. After 5 years he returned to teaching. In 1983 he retired from full time teaching, but continues to teach part time, and is actively involved in many other activities related to horticulture. Our distinguished 1986 recipient of the Curtis J. Alley Award of Merit is Dr. Howard C. Brown, a long time friend of horticulture and the IPPS Western Region.

QUESTION BOX

Moderated by Bruce Briggs and Ralph Shugert

BRUCE BRIGGS: How do you propagate *Juniperus scopulorum*?

VOICE: It depends upon the cultivar. Some are easy to root—others not. Use 6000 ppm IBA or 3000 ppm NAA. They take a long time to root, 5 or 6 months. Start them late in the season—November.

BRUCE BRIGGS: Do you use talc or the liquid hormone in your rooting?

VOICE: We use all liquid.

BRUCE BRIGGS: If you are rooting *Juniperus horizontalis, J. sabina,* and *J. chinensis,* do you take cuttings all at the same time for best rooting, or at different seasons?

VOICE: we start in late summer and early fall with *J. horizontalis* and *J. chinensis,* which are easiest to root, then we go into the more difficult ones later in the season; when it warms up in the spring we go back and finish the *J. horizontalis.*

BRUCE BRIGGS: In rooting our rhododendron cuttings, they do not root around the edges of the bench. What is the reason for this?

DUANE SHERWOOD: It could be due for one thing, to toxic effects of copper naphthenate in the wooden bench.

RALPH SHUGERT: How is the best way to propagate *Clematis armandi*—by seeds or by cuttings?

DUANE SHERWOOD: For seeds you should harvest and plant before dormancy sets in, otherwise it is difficult to overcome seed dormancy.

RALPH SHUGERT: What is the best way to propagate *Hydrangea anomala* subsp. *petiolaris*?

DAVID HILL: We use seed collected in December and germinated in January, then collecting cuttings from the seedlings. Cuttings taken from stock plants will also root.

RALPH SHUGERT: Is there some information on propagation of Pacific madrone (*Arbutus menziesii*)?

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RALPH SHUGERT: Is there some information on propagation of Pacific madrone (*Arbutus menziesii*)?

ED SCHULTZ: I noticed that seeds would start germinating around areas where madrone brush had been burned, so I concluded that the seeds needed the lye coming from the ashes, so I washed seeds with a strong lye soap, which may have given them a mild scarification. From this I received a fair—not good—germination.

BRUCE BRIGGS: There are articles in back issues of the PROCEEDINGS describing the burning of excelsior or straw on top of flats of seeds to promote germination, using the effect of heat to rupture impervious seed coats.

RALPH SHUGERT: Has anyone growing liquidambar observed variations from the typical pyramidal form?

PHIL BARKER: If you look at enough seedlings you will find variations, some spreading and some not. A useful variation was reported about 30 years ago in North Carolina that had neither flowers or fruit.

RALPH SHUGERT: Variations certainly can occur in liquidambar. A cultivar called 'Gumball' was introduced about 40 years ago in McMinnville, Tennessee by the U.S. Forest Service. The tree grew for about 10 ft. then formed a perfect round ball.

RALPH SHUGERT: Why do some palm seeds take a year to germination while other seeds will germinate in only 2 weaks?

DUANE SHERWOOD: I have heard that in all seeds the last thing to develop is dormancy. If you pick the seeds early enough it will have no dormancy. The palm seed effect may be related to the harvesting date.

RALPH SHUGERT: Explain the freezing of *Cornus kousa* seed in relation to germination.

I ran some tests on this—finding that freezing the seeds for 3 months, then soaking in water for 24 hrs.—gave excellent germination.

BRUCE BRIGGS: How is it best to handle *Daphne odora* in tissue culture?

BOB TICKNOR: We have rooted daphne conventionally best in a 20% compost and sewage sludge in the mix, as compared to straight perlite. We have not used tissue culture.

DUANE SHERWOOD: Some growers of daphne have found that they must add a lot of calcium to the soil to get them to grow.

BRUCE BRIGGS: Another thing—daphne plants seem to be short-lived in the U.S., which may be due to viruses. We do not have virus-free stock in this country.

RALPH SHUGERT: How do you harden off Japanese maple for the winter to prevent winter injury?

STEVE HOTTOVY: Reduce fertilizers, especially nitrogen, in late summer after budding to reduce growth.

RALPH SHUGERT: Where can we obtain effective, comfortable masks for spraying? Also, spray uniforms that are effective, yet relatively cool.

RALPH SHUGERT: I will answer this one. We use the very best respirator masks we can find, but it is still not likely to be very comfortable. We use paper coveralls, used only one per day then thrown away.

BRUCE BRIGGS: How effective is K-IBA, which is water soluble, compared to indolebutyric acid dissolved in alcohol?

ED WOOD: In tests we conducted with Bob Ticknor, there were slight differences in results, but K-IBA is more expensive, and the extra costs may not justify the better rooting.

RALPH SHUGERT: How do plants (or cuttings) behave at very high temperatures (95° to 115°F) under fog?

MARGARET SCOTT: We have had some experience with this in rooting cuttings. We found no adverse effects on rooting, provided we kept the humidity at a very high level.

PHILIP McMILLAN BROWSE: Cuttings of *Acer palmatum* and *A. japonicum* cultivars were rooted in July in closed, well-damped-down poly tunnels, without mist lines. Temperatures were well over 100°F, but they rooted and grew very well.

VOICE: Loblolly pine cuttings rooted very well at temperatures over 100°F but with 100% humidity.

RALPH SHUGERT: What is the average salary for the head propagator at a nursery—or what is an industry-wide average for this position?

RALPH SHUGERT: In my experience it would depend upon several factors: 1) experience in the commercial trade; 2) education; 3) track record at previous job; 4) part of the country you are in.

PROPAGATION OF BANKSIA COCCINEA BY CUTTINGS AND SEED

MIKE BENNELL
Blackhill Native Flora Nursery
Athelstone, South Australia
GAIL BARTH,
South Australian Department of Agriculture
Adelaide, South Australia

INTRODUCTION

Banksia coccinea is one of a number of Western Australian species being developed for commercial cut-flower production. Reliable methods of vegetative propagation are required so that selected individual plants can be clonally propagated and trialed by research institutions and growers.

This species is reputedly propagated by cuttings by some nurserymen but so far no published information is available on the best methods. Generally this species, along with several other desirable banksia species, has a reputation of being difficult-to-root and commercial practice is seedling production. (Note the effect of temperature on seed germination of *B. coccinea* at the end of this paper).

George (2) states that cuttings of many banksia species, including *B. ericifolia*, *B. spinulosa*, *B. pulchella*, *B. nutans*, *B. integrifolia*, and *B. seminuda*, strike root without auxin treatment and that, in some cases, the application of auxin may be lethal. Other authors have reported that auxins promote rooting in some banksia species. Watkins and Shepherd (3) found that *B. occidentalis* rooted best following a 10-sec. dip in a 3,500 ppm solution of indolebutyric acid (IBA). Cuttings of *B. spinulosa* var. *collina*, *B. integrifolia*, and *B. burdettii* rooted under mist following treatment with a concentrated IBA solution (1).

Propagation of many species and cultivars of the South African PROTEACEAE is routinely done by striking cuttings. Cuttings are treated with an auxin, usually IBA at 4,000 to 8,000 ppm dissolved in a 50% ethanol solution (4).

The beneficial effects of auxins in promoting root initiation on cuttings and the great variation among species in their response to auxin concentration has been widely noted. The present experiment was undertaken to determine the optimum concentration of IBA to promote root initiation in *Banksia coccinea*. Also the effect of cutting wood maturity (soft versus semi-hardwood) on rooting was examined.

Materials and Methods. Experiments were conducted at Blackhill Native Flora Nursery, Adelaide, South Australia during spring, 1985. Cutting material was collected from cultivated trees of *B. coccinea* being grown on a commercial cut-flower plantation at Blewitt Springs, South Australia. The semi-hardwood cuttings were taken from wood which grew during the previous spring growth flush.

The cuttings were stored in a refrigerator overnight and were prepared and treated on the following day. Prior to preparation and treatment the cuttings were dipped in a 5% sodium hypochlorite solution for approximately 30 seconds and subsequently washed in water. Cuttings were prepared by stripping the lower two-thirds of leaves and cutting the basal end at a node. The base of each cutting was wounded by making 2 longitudinal cuts 1 to 2 cms in length, penetrating the bark. The basal 1 cm of cuttings was dipped in IBA solutions (50% ethanol) for 5 seconds.

The following treatments were included in this trial:

A) Terminal semi-hardwood cuttings prepared with the apical bud removed. A range of IBA concentrations from 0 to 16,000 ppm was used.

B) Softwood cuttings prepared as above and treated with 0 to 12,000 ppm IBA.

C) Basal semi-hardwood cuttings collected 20 to 30 cm from the shoot apex. Auxin was applied at 2,000 and 6,000 ppm.

Each treatment consisted of 25 cuttings placed in 6 in. pots containing a 1:1:1 mix of peat/perlite/sand. Cuttings were placed under intermittent mist with bottom heat at 25°C. The glasshouse temperatures were maintained at 30° day, 15° night. Cuttings were lifted and examined for rooting at 12 and 18 weeks.

Results. The results obtained at the 12 and 18 week assessments are presented in Table 1.

The effect of IBA concentration on rooting of *B. coccinea* cuttings was found to be significant by analysis of variance. The 8,000 and 12,000 ppm IBA treatments gave a significantly higher rooting percentage than the control or 2,000 ppm IBA treatments. Maximum rooting was 88% at 12,000 ppm IBA (at 18 weeks), with 8,000 ppm giving 84%. Also, the higher IBA concentrations were found to result in a significantly higher number of roots per cutting. The length of roots (as determined by measuring the longest root per cutting) was not significantly affected by the IBA concentration.

A lower percentage of cuttings rooted was recorded for basal cuttings at 18 weeks (60% versus 84% at the 8,000 ppm IBA treatment); however, the difference was not statistically significant.

Table 1. Rooting of *Banksia coccinea* cuttings at 12 and 20 weeks.

Type of cutting	Treatment (ppm IBA)	Percent rooted 12 wks	Percent rooted 18 wks	Mean No. roots/cutting at 18 wks.	Mean length roots/cutting at 18 wks.
Terminal Semi-hardwood					
1.	0	12	44	1.6	4.3 cm
2.	2,000	12	40	1.6	4.6
3.	4,000	40	64	2.4	5.2
4.	8,000	60	84	3.8	5.1
5.	12,000	56	88	3.2	5.4
6.	16,000	44	48	5.2	4.4
				(Significant) (LSD = 2.3)	(not signif.)
Terminal Softwood					
7.	0	0	0	All softwood cuttings were	
8.	2,000	8	16	severely damaged by	
9.	8,000	20	32	fungal infection with a	
10.	12,000	10	12	resultant high mortality.	
Basal Semi-hardwood					
11.	2,000	16	44	2.2	4.6
12.	8,000	48	60	3.1	4.5
				(not signif.)	(not signif.)

Root initiation was noted to occur under the bark either on the base of the cutting or along the wound. Callus development was slight in most cases, with small nodules developing under the edge of the bark.

A relatively high rooting percentage (44%) was obtained for the control (0 ppm IBA) after 18 weeks; however, root development and percent rooted was better when IBA was applied.

Recommendations. The results of this trial show the benefits of applying IBA at concentrations of 8,000 to 12,000 ppm to semi-hardwood cuttings. All available cutting material should be utilized regardless of position on the stem. It is suggested that cuttings be wounded and inserted in a porous mix under intermittent mist with bottom heat. Care should be taken that mist systems are well-adjusted and leaves do not remain permanently wet, as banksias are inclined to drop leaves during long rooting periods.

It is suggested that in commercial practice, cuttings be struck in individual tubes and care taken when potting-on so as not to disturb the roots. In our trials up to 50% of the cuttings died when potted on, probably due to root disturbance necessitated by recording of the data.

In nursery practice we recommend that a low phosphorus (0 to 2%) slow-release fertilizer be incorporated in the potting-on mix. In our experience cuttings developed rapidly, producing two or three

30 to 40 cm shoots at 6 months. Rooted cuttings may be field-transplanted once they have hardened after moving from the greenhouse. If they are to be held longer in the nursery, care should be taken to keep the plants actively growing by regular repotting as necessary. Plants that are stopped by nutrient or water stress seem to quickly yellow and fail, or are slow to renew growth when transplanted.

SEED PROPAGATION

At present, *Banksia coccinea* is almost exclusively propagated from seed. Until clonally propagated plants become widely available, this method is likely to remain the usual means of commercial propagation.

Temperature is one of several factors which may influence seed germination and, to date, its effect on seeds of the majority of Australian species is poorly understood. *Banksia coccinea* is one of many being studied in an on-going seed testing program being undertaken at Black Hill.

Materials and Methods. The Flora Research Section at Black Hill has recently developed a seed testing machine enabling seed testing over a 10 to 35°C range, at either constant or alternating temperatures.

Banksia coccinea seed obtained from a commercial seed merchant was tested at the following constant temperatures, i.e., 10, 15, 20, 25, 30, and 35°C, and alternating temperatures (18 hr day/6 hr night), i.e., 35/25, 30/20, 25/15, and 20°/10°C. Germination experiments were carried out in the dark.

Results and Discussion. The number of seeds germinated (G) and the time to achieve 50% of the maximum number germinated (T50) is listed in Table 2.

Table 2. Effect of temperature on *B. coccinea* seed germination.

Treatment (°C)	G[1]	T50[2]
10	28	18
15	32	13
20	32	24
25	30	43
30	6	54
35	0	
35/25	0	0
30/20	16	56
25/15	31	37
20/10	31	24
LSD	10.6	4

[1]100 seeds/treatment
[2]days

The following temperatures resulted in a similar number of seed germinated (approximately 30%) i.e, 10, 15, 20, 25, 25/15 and 20°/10°C. There was no significant effect of temperature on the number germinated over the 10° to 25°C range. However, temperatures above 25°C severely inhibited germination.

Temperature did have a significant effect on the rate of germination over the 10 to 25 C range. The optimum temperature is approximately 15°C with T50 = 13 days. This temperature was significantly better than all others. Germination at a temperature of 25°C or greater required 40 or more days to reach the T50.

Recommendation. Seed of *B. coccinea* should be germinated at a temperature of 12 to 18°C. Germination should occur within 20 days.

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ENSURING AN ADEQUATE SUPPLY OF SULPHUR TO PLANTS IN CONTAINERS

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Preliminary results of an experiment on the supply of sulphur (S) to plants in containers were reported in my IPPS paper in 1985. (1). I stated that if a liquid feed is the sole source of S for plants in containers then that feed needs to contain at least 15 ppm S for some species and at least 25 ppm S for others.

Those figures were used before an adequate statistical analysis was made on the data. This has now been done and the results of a number of other experiments analyzed, as well.

This paper summarizes these results and offers some guidelines for ensuring that your plants are never short of sulphur.

Sulphur—an essential element. Sulphur is an essential nutrient which plants take up mainly through their roots as sulphate ions (SO_4 =). Other forms of sulphur such as elemental sulphur (yellow powder), or sulphur present as part of soil organic matter must first be converted by microorganisms into sulphate ions. Inside the plant, the sulphur of these sulphate ions is used in making proteins and many other compounds. Plant tops typically contain about the same concentration of sulphur as they do of phosphorus—0.2 to 0.4% in the dry matter. Sulphur has been aptly named "the fourth major element."

Severe sulphur deficiency shows up first in the youngest leaves, which tend to be small, erect, and yellow all over. Mild deficiency, which comes on slowly, tends first to make all leaves a pale green colour. The youngest leaves may remain greener than the oldest leaves, which gradually die from the base of the plant upwards. The symptoms are very similar to nitrogen deficiency.

Sources of sulphur. In most soils the main source of sulphur is organic matter. Sulphur is released as sulphate ions from organic matter as it is decomposed by microorganisms. Gypsum (calcium sulphate) is another major source of sulphur, and some sulphate ions may be held on the surfaces of minerals in exchangeable form.

The wood wastes and peat used in potting mixes contain very little sulphur and little sulphate-sulphur is released from them as they decompose. An additional source of sulphur must be provided for plants in containers when these mixes are used.

Superphosphate, gypsum, sulphates of trace elements (eg. as in iron sulphate and Micromax) and such slow-release products as Osmocote and the sulphur-coated products all provide sulphur

to plants. Liquid feeds may contain sulphates of ammonium, potassium, magnesium, iron, and other trace elements but some are formulated without them. All irrigation water contains some sulphate-sulphur, but the concentration varies widely. Thus, Melbourne tap water may contain as little as 0.3 ppm sulphur, while Perth water may contain 40 ppm or more. Air also contains some sulphur dioxide (SO_2) and various other sulphur compounds. Plants can take up sulphur from sulphur dioxide. In areas where the air is polluted with sulphur dioxide, plants can get part of their sulphur from this source.

Why is more sulphur needed? Sulphur has frequently been ignored in fertilization programs in nurseries, perhaps mainly on the assumption that the fertilizers used or the water supply should be providing enough. Many commonly available fertilizers do not even list their contents of S. Such assumptions are valid in some situations but they are certainly not universally valid. Feedback I have received from growers as a result of my paper at Rockhampton (1) and from others at various meetings has convinced me that mild sulphur deficiency is widespread in nurseries in areas where the water supply contains little sulphur, and where the air contains little sulphur dioxide. It is very widespread in homes where rainwater is used for watering plants in pots.

A main reason for deficiencies is that the materials used in soilless potting mixes have almost no ability to retain sulphate ions against leaching. Almost all of the sulphur from very soluble sources such as the sulphates of ammonium, magnesium, potassium and iron is lost in the drainage water in a couple of weeks. The sulphur of the less soluble gypsum and superphosphate is almost totally lost in 4 to 7 weeks under typical nursery conditions. Whether these losses cause deficiency to develop depends on the concentration of sulphur in the water supply and on whether there is a slow-release source in the mix.

Ensuring an adequate supply of sulphur. Rather than go through the results of all of my experiments, I now summarize the conclusions I have drawn from them and other observations. I stress that these conclusions have been reached on the basis of experiments with a limited range of plant species. Some adaption will be needed for other species and growing conditions.

The maximum amounts of sulphur I specify should be adequate for all plants likely to be grown, but I don't know how much less than the maximum will be adequate for the bulk of the wide range of plants grown in Australian nurseries.

1. *If your water supply contains at least 25 ppm sulphur.*

You are fortunate. Your plants will be getting enough sulphur so long as all watering is with this water. Sulphur deficiency could show up in plants grown outside and watered by rain alone for extended periods, if there was no other source of sulphur in the mix.

2. *If your water supply contains 15 to 25 ppm sulphur.*

Plants of many species will grow quite well when all of the water contains a concentration of sulphur in this range. As in 1 (above), a sulphur deficiency is most likely to show up during extended periods of watering by rain, if all other sources of sulphur are inadequately provided. So far as I know, the only plants needing sulphur at concentrations at the upper end of this range are the crucifers—brassicas, stocks, *Cheiranthus*, etc. Many fast-growing broad-leaved plants may need concentrations of sulphur in the middle to upper end of this range.

My guess is that most plants will be well-supplied with 15 to 20 ppm sulphur in the water supply as the sole source of sulphur.

3. *If your water supply contains 10 to 15 ppm sulphur.*

This is where we get into uncertain territory. Some plants will grow well at 10 to 15 ppm sulphur, but they are likely to be slow-growing species. There is probably little in the way of reserves in the plant when water with this sulphur concentration is the sole source of sulphur. Any sudden decrease in supply, as would be brought on by prolonged rainy weather, could easily lead to deficiency.

4. *If your water supply contains less than 10 ppm sulphur.*

Many plants will be struggling if the water supply contains much less than 10 ppm sulphur and there is no other source of sulphur in the mix. Some may look healthy enough near 10 ppm, but if it was possible to compare them with adequately fed plants it would be obvious that they were somewhat stunted and pale. In this range it is essential, for many species, to provide some other source of sulphur. However, the grasses, and perhaps other mono-cotyledenous plants (including orchids?) and species which grow slowly may manage quite well on 10 ppm sulphur or even less.

Providing More Sulphur

a. *Liquid feed*

If you normally fertilize by means of a liquid feed, all that is needed is to ensure that the feed contains enough sulphur to give the desired 15 to 25 ppm. This is easy enough if you make your own feed. Just include some ammonium, potassium or magnesium sulphate in it. A feed containing 20 ppm sulphur is given by dissolving, respectively, 8.2, 10.9 and 15.4 g of these sulphates per 100 litres of actual feed. You need to multiply this up to take account of the dilution setting on your injector. The requirement for 15 to 25 ppm sulphur refers to the situation where all irrigation water is to be liquid feed. If you apply liquid feed only once a week or less frequently you should increase the concentration of sulphur in that feed to 30 to 60 ppm to allow for use and leaching during the periods when irrigation is with water only. There is no benefit to be gained from higher concentrations, and some harm may by done if the extra sulphate increases salinity to a toxic level.

If you use a proprietary feed, calculate from the label the

concentration of S to be expected in a liquid feed made from it. If there is no information about S on the label, try to find out from the manufacturer or switch to a brand which does give this information.

b. *Single superphosphate or gypsum.*

Most of the sulphur in a typical granulated superphosphate will be taken up by plants or lost from soilless media in drainage water within 6 to 7 weeks when watering is from overhead. Using very coarsely granulated superphosphate will somewhat prolong the period of release. Most of a 1 or 2 g per litre addition of phosphogypsum or fine dune gypsum will be gone in about 40 days. Crushed rock gypsum of 1 to 4 or 5 mm size, added at about 2 g (½ standard teaspoon/litre), will provide a steady supply for several months.

The point at which superphosphate or gypsum needs to be reapplied to pots depends on the concentration of sulphur in the water supply and liquid feed and on whether there is another slow-release source of S in the mix. Clearly, the poorer the supply from other sources, the sooner extra superphosphate or gypsum, or another source of sulphur needs to be added.

c. *Slow-release fertilizers*

Fertilizers such as Nutricote, Osmocote, Osmocote Plus, Biocote, and the sulphur-coated products all contain sulphur, but they vary in the amount released in a given time, and in the time until all the sulphur has been released. I have only tested the first three products.

The sulphur in Nutricote is very poorly available. One Nutricote formulation (13:5.7:9.1; 8 to 9 month) released little sulphur and is an ineffective source of sulphur. When added at 9 g/litre, two 3 to 4 month formulations were unable to supply enough sulphur for adequate growth of at least one species of test plant. The symptoms of a sulphur deficiency were made worse if a dilute liquid feed containing a very low concentration of sulphur (0.01 ppm sulphur) was also supplied.

This finding explains, among other things, the often poor performance of Nutricote in southern Victoria, where water supplies contain litle sulphur. Nutricote's limited ability to supply sulphur is, in my view, at least as much a reason for its poor performance as is its reputed inability to release N, P and K fast enough in cold weather.

In some nurseries the combination of Nutricote and Phostrogen has a proven track record. One supplies N, K and some P and the other supplies these and sulphur. If your water supply contains a suboptimal concentration of sulphur and you want to use Nutricote, you must add another source of sulphur as well.

Osmocote with a nominal release time of 3 to 4 months should be capable of supplying enough sulphur to keep pace with the release of other nutrients, so long as there is at least a few ppm sulphur in the water used. Whether the formulations with longer

release times can do this too, is not clear from my work. Certainly the longer the nominal release time, the slower the rate of release of sulphur. The question really is whether, if this type of Osmocote is the main source of nutrients, the rate of release of sulphur is fast enough to allow full use of the other nutrients. My guess is that when the concentration of sulphur in the water supply is very low, some supplementation is desirable, but probably only some months down the track. Supplementation is probably unnecessary within the nominal release time if the water contains at least 4 to 5 ppm sulphur.

The Osmocote Plus formulation which I tested had a 3 to 4 months nominal release time. It certainly did not need any supplementation even when the water used contained less than 0.01 ppm sulphur. In fact the rate of release of all nutrients from this formulation of Osmocote Plus was such that growth produced by it when added at 6 g/litre was as good as that from a continuous liquid feed containing 175 ppm N, 20 ppm P, 140 ppm K, and 30 ppm S. The results also suggested that the nutrients might run out well before the end of the nominal release time in warm to hot conditions.

In summary then, of the slow-release fertilizers I have tested so far, Osmocote Plus needs no supplementing with extra sulphur, Osmocote might need a little extra if the water supply contains a particularly low concentration, and Nutricote certainly does need supplementation if the water supply contains less than perhaps 10 ppm sulphur.

Checking your situation.

A first step is to find out the concentration of sulphur in your water supply. Your water supply authority will be able to tell you. If your water is from a bore or dam there are laboratories which will analyze it. You can then take action on the basis of the information given above.

Another check is to sprinkle fine gypsum or ground superphosphate over some of the pots in a reasonably uniform batch. Your usual watering and fertilization program should continue for the whole batch. Any greening of the plants in the treated pots over a period of 7 to 10 days, but not in the other pots, indicates a need for extra sulphur. The rate of sprinkling can be equivalent to about 2 g (½ standard teaspoon) per litre of mix.

There is ample evidence that cuttings in propagation benches need nutrients as soon as roots start to form. An adequate supply of soluble sulphur is as necessary then as it is during later stages of production.

Full accounts of the experiments on which the statements in this paper are based are being published in *Scientia Horticulturae*.

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Meadows, S.A., and the S.A. Woods and Forests Dept. for gifts of potting mix materials, to Australian Gypsum Ltd for samples of gypsum, and to Barbara Graham for technical assistance during some of the experiments.

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GREENHOUSES IN PLANT PROPAGATION: AN HISTORICAL PERSPECTIVE

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The growing of plants in covered houses, whether they be greenhouses, conservatories, or orangeries, is essentially a northern hemisphere phenomenon. It is not, however, a new phenomenon, and the first attempts at growing plants under artificial conditions go back to at least early classical times. For countless generations much use has also been made of "shade houses" or natural cover to allow the cultivation of many plants which were affected by excess sunlight.

The Greeks with their "gardens of Adonis" appeared to have had forcing houses in miniature. Plato says that "a grain, a seed or a branch of a tree placed in or introduced to these gardens acquired in eight days a development which could not be obtained in as many months in the open air." Columella, a Roman writer on rural matters, speaks of Rome possessing "within the precincts of her walls, fragrant trees, trees of precious perfumes such as grown in the open air in India or Arabia." The implication of this is that they were not grown in the open air in Rome. It was Caesar Tiberius, however, who, introduced a utilitarian note to these early attempts at covered gardening. Told by his doctor that he needed a cucumber a day to cure an illness, he instructed his gardener to produce a cucumber a day or else! The gardener succeeded in growing cucumbers by cultivating them in pits filled with fermenting dung and covered with frames or lights of talc or mica.

In later Roman times forcing was done my means of specularia, buildings covered with sheets of mica, thinly split. Mainly fruits, cucumbers, and peaches were grown in specularia. Among the ruins of Pompeii a building of this kind was discovered, with

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masonry staging for displaying plants and hot air flues in the walls; it was apparently originally glazed with talc or rough glass.

With the decline of the Roman empire the practice of forcing fruit in artificial conditions seems to have been abandoned in Europe, and not until the 13th century do we hear of any attempt to revive it. In 1295 Albert Magnus, a Paduan, is said to have entertained William of Holland, King of the Romans, in a garden maintained in flower and fruit by artificial heat. The wealthy merchants of Venice and Genoa, importers of many luxurious fruits, were probably the next to attempt glasshouse construction.

Further north, the earliest development of the greenhouse appears to have taken place in France: this lead was subsequently taken by the Dutch, when at the height of their maritime empire, and it passed ultimately to Britain. The first covered gardens were orangeries, normally without heat, built for sheltering citrus fruits during the winter months, but by the seventeenth century these had reached a fair degree of perfection. In 1685 Jules Mansard (or Mansart) built the noblest orangery in Europe for Louis XIV at Versailles. It had three arcaded galleries, the central portion of which was 508 ft long, 42 ft wide and 45 ft high. In 1693, Fagon, Superintendent of the Jardin Royal, constructed the famous hothouse which he warmed with "stoves and furnaces for the preservation of tender plants, including the tea plant. The first successful attempt in Britain at greenhouse gardening was made at the Physic Garden at Oxford where the buildings were of wooden construction, very little better than cold frames.

In general, orangeries, which were unheated, came first; these were followed by conservatories, essentially houses for conserving tender plants; the stovehouse which was heated to a high degree came later. The credit for coining the word greenhouse (a house for conserving tender greens) goes to the diarist Englishman, John Evelyn.

In the early days the greatest problems related to heating and all sorts of fantastic methods were used. The Dutch first used freestanding stoves which had to be fuelled from inside the greenhouse. It was fairly soon realized, however, that fumes from the stoves were destroying the plants, and quite a number of gardeners also appear to have been choked to death by these early furnaces. Even more primitive was the portable brazier, filled with burning coals and wheeled to and fro, used to heat the first greenhouses at the Oxford Physic Garden. Subsequent developments involved moving the stove outside and heating the back wall of the greenhouse by means of complicated flues.

At this time the only people who had greenhouses were the very wealthy. In Britain there was no real progress made in glasshouse development until the tax on glass was repealed in 1845. Every gentleman with any self-respect had to have a greenhouse. The

aristocracy really became enthusiastic and a number of structures similar to the Palm House at Kew Gardens were erected, perhaps the most famous being the huge conservatory built by Paxton for the Duke of Devonshire at Chatsworth.

Another major breakthrough occurred when hot water heating for greenhouses was invented. Incredible though it may seem, until 1818 nobody realized that hot water circulated naturally. Once this principle had been understood all manner of boilers were invented, the manufacturers of each one claiming invariably that their boiler presented a larger area of water to the fire than anyone else's and was therefore a more efficient heat exchanger. One wonders what the proud possessors of the first boilers would have thought of a modern small bore, or mini-bore, heating system! The next problem, of course, was how to ventilate the heated greenhouse efficiently, while keeping it at an acceptable temperature to the plants being raised.

Once electricity became available, further advances followed in greenhouse development and as long as it was cheap, many greenhouses used it for heating to high levels. Today, electricity is used mainly for heating to moderate levels, but is essential for the operating of almost everything else in greenhouse mechanics. It is also used for artificial illumination, both so that one can see in the greenhouse after dark and to encourage the growth of plants with long-day requirements, for automatic ventilation and shading, and for air circulation.

Thus, although greenhouses have developed rapidly and have come a long way from the earliest attempts by the Romans in classical antiquity, the basic problems faced by greenhouse designers and engineers today are still the same as they were in those days and, indeed, throughout the whole history of the development of greenhouses, including the heyday of the Victorians. The giant conservatories at Chatsworth House faced precisely the same problems as the 8 by 12 ft greenhouse found so frequently in private gardens today. The difficulty has always been to find an effective balance between heating and ventilating, and between light and shade. Too much heat and the plants boil to death in their own condensation; too much ventilation and it becomes almost impossible to raise the temperature to the desired level; too much light and the greenhouse overheats in summer; too much shade and the plants become drawn and leggy. However, with modern electric and other automatic aids it is now possible to overcome all these problems and to have a greenhouse that is not only more efficiently heated, ventilated, lit, and shaded than ever before, but also to have these elements in proper balance and so automatic in their running that the greenhouse can virtually be left to itself. All the modern greenhouse gardener need do is enjoy his plants.

SITE SELECTION

I assume that some of you will be contemplating building a new complex and where you build and how you build will be uppermost in your minds. Some of you will already have a greenhouse and may not have had a choice on site selection.

The nearer you are to the equator the nearer you are to the sun. If you journey away from the equator the colder it can get. This is important in the winter when heating may be required, and the cost of heating fuel can be one of the biggest costs in running a greenhouse.

Since water stores heat, it is quite often an advantage to build a greenhouse close to the coast to take advantage of the heat radiated back to the air.

Some areas can get extremely hot with 40°C+ temperatures. With modern day cooling equipment, these can usually be easily handled, but again with a running cost.

For the milder climate, roof and/or side venting may be sufficient, and in the high humidity areas it may be the only real way to go. Natural venting does not cost anything to run and is very quickly coming back in favour with many growers.

Depending on the plant you are growing, when you want to grow, and where you want it to grow, it may be that you would need to have cooling and natural venting, with heating as well.

I am not going to enter the debate of whether a greenhouse should face north to south or east to west—there are growers who are adamant that only north to south is correct. Their ideas may well be correct but I believe that Australia has an abundance of light as compared to other countries and it does not make a lot of difference; also, with the use of fiberglass and plastics, the light entering the greenhouse is much more even, thereby minimizing shadows from structures, etc.—more of that later.

THE MODERN STRUCTURE

The present day structure is usually made of hot dipped galvanized steel with a few glazing members of aluminium—all designed to be low in maintenance. The structure will also be slim in its sections to minimize shadows, but yet it has to be strong enough to withstand any adverse weather conditions.

All-aluminium structures are available, but not all that popular since they cost more to manufacture and have no definite advantages in the final performance.

Designed into the structure will be a means of collecting and draining condensation which forms inside the glazing. This will minimize damage to the plants from falling droplets and reduce the likelihood of humidity related diseases which require expensive spray control.

The modern greenhouse will be well sealed to reduce cold drafts and also keep the heated warm air inside—which has cost you money to get. It is also necessary to have the greenhouse sealed for the modern cooling systems which are negative pressure operated.

GLAZING ALTERNATIVES

To glaze the greenhouse, there are so many options that you could be excused for being confused.

If you are thinking of using polythene you probably have more decisions to make than anyone else. There must be at least 10 different polys on the market, ranging in quality and cost with all kinds of performance claims. Some come in a choice of light transmissions and then you need to decide whether you have a single or double skin and how you will fasten it all. In initial cost poly would be the cheapest but can also cause more heartache than either fiberglass or glass. If you count the material and labour cost of frequent replacement and the very real possibility of losing the cover with a crop in a high wind—I suggest it may not be that cheap after all. In fact 50% of our business comes from disgruntled poly users.

The debate continues on the merits of using fiberglass or glass. I prefer fiberglass because it has a host of advantages. It can be purchased in several choices of light transmission, and I don't know of any plant that will not respond better under fiberglass than glass. The light transmission is much softer—much like comparing a soft 40-watt florescent light with a harsh 40-watt incandescent bulb. It reduces heavy shadows from the structure. Tests taken have shown fiberglass will actually allow more light in at the beginning of the day and at the end of the day when compared with glass, thereby lengthening the day. It will not shatter from hailstones or cricket balls and it is much easier and quicker to fix on site which means lower construction costs. Although fiberglass bought in 1986 has protective coatings and is much improved from only five years ago, it still loses its light transmission by about 1% per year. This means that fiberglass bought today at say 90% light transmission will, in effect, be about 80% in ten years time. Now this would possibly not concern too many growers with the abundance of light in Australia. Growers have repeatedly told me that they are growing a better product now than they were when the greenhouse was new. It could well be that we are brainwashed into believing we need all the light possible, from literature obtained or reproduced from overseas where light is not in abundance. It could also be that the grower has gained experience in those years and treats his plants differently.

Glass is the other alternative that requires a mention. For all intent, it will last forever and is not affected by reducing light transmission. Glass by itself lets in a lot of light but with the necessary glazing bars the overall light transmittance is not a lot different from

fiberglass. Hailstones are not the big threat they used to be with the change from 3mm to 4mm in thickness, although a hail guard is still desirable. Glass is harder to fit around doorways, exhaust fans, etc. and as mentioned, field erection times are considerably more with the glazing bars, sealers, and smaller panels. It also seems that its easier to insure a fiberglass house than a glasshouse.

HEATING

There is no doubt that when heating is necessary it is usually the costliest item that occurs in the operation of a greenhouse.

Oil, gas, and electricity are extremely costly and there does not seem to be any reductions of price for growers in the foreseeable future. Maybe this is an area where organizations such as IPPS could do some lobbying.

The success of a greenhouse manager lies, in part, with his ability to maintain desirable and uniform temperatures during the heating season. A properly sealed greenhouse and properly designed, installed, and maintained heating system is a necessity to be able to operate as economically as possible.

There are many heating systems available ranging from hot water boilers, unit heaters, infrared heaters, electrical cables, and electric fan forced units. Depending on the size of the greenhouse, the types of fuel conveniently available and what the grower wants to achieve, will usually determine the type of heating system to be installed.

It is claimed that a thermal blanket system can save 30 to 40% of heating costs, and a fully automatic system would pay for itself in two or three years.

Many experiments have been made with solar heating, and whilst the costs of running are lowered, it is costly to install and a "back up" system would still be necessary for those days when the sun is not releasing enough of that free energy.

COOLING

Prior to the mid-1950's, little was mentioned in texts regarding principles, methods, and equipment used in ventilating greenhouses. Little did an American named Bailey realize, when he wrote in 1900, that some of his 100-word description of ventilation would be the goal of engineers 50 years later. He wrote of ventilation:

> "Theoretically, it is employed also for the purpose of introducing chemically fresh air, but with the opening and shutting of doors, and the unavoidable leaks in the house, it is not necessary to give much thought to the introduction of mere fresh air. Ventilating reduces the temperature by letting out warm air and letting in cool air. The air should be admitted in small quantities and at the greatest distance from the plants in order to avoid

the ill effects of drafts on the plants. Many small openings are better than a few large ones. Ventilate on a rising temperature."

Bailey had made some observations, which are quite correct, but he was not to be aware of the progress that has been made with greenhouse design.

Today's greenhouses have roof and side ventilation which can be opened and closed and, if you wish, are operated automatically by micro-processors.

In 1954, DeWerth and Taska in the U.S., pioneered a new method of ventilating greenhouses. It could be classed as forced ventilation but is commonly known as pad and fan cooling. It took another 20 years, to 1974, before a suitable standard was established for engineers to work on for ventilation requirements.

This standard is now accepted on a world wide basis and gives the grower an environment in his greenhouse that is, combined with other factors, just about as perfect as one could hope for.

The system works best in the hot dry areas and we now see plants, flowers, fruit and vegetables all year round that only a few years ago were simply not available.

CONCLUSIONS

Yes, greenhouses have come a long way in a short time. They have become sophisticated in their design, they can grow almost anything almost all year round; they are also able to do it automatically.

I am told by experts that the horticultural industry is one of the few growth industries (and that is not meant as a pun) in Australia. It has an excellent future, providing we can hold costs to a minimum and keep pace with technology which will produce good, new products for a reward, which gives us incentive to continue.

THE ROD TALLIS MEMORIAL AWARD

This award was set up in memory of the late Rod Tallis, a young Sydney nurseryman who had been very active in IPPS. The award is offered each year in the State where the Conference is being held. Young people under 25 years of age in nurseries, educational institutions, and government departments who have an interest in plant propagation are invited to apply.

The applicants, who need not be members of IPPS, must outline why they should be given the chance to attend the IPPS Conference. They also have to present a biography and outline their interest in horticulture and plant propagation.

The winner of the award attends the Conference as a guest of the Society and must prepare a paper for presentation at the Conference. The winner also receives a book award.

In 1986 Alison Fuss, a student at the Waite Agricultural Research Institute, won this year's award and presented the following paper:

GLASSHOUSE PEACHES: FORCING OF BUD BURST AND ITS EFFECT ON FLORAL DEVELOPMENT

ALISON FUSS[1]

Waite Agricultural Research Institute
Waite Road
Urrbrae, South Australia

Murray Bridge, which is 85 km southeast of Adelaide, is one of South Australia's significant glasshouse areas. In the past, tomatoes and cucumbers have been the main crops grown, however at present such crops are unprofitable. In this economic situation there has been a great interest shown by the growers in finding alternative crops which will bring greater returns.

Following the success of temperate-zone fruits, such as apples and peaches, in the tropical and subtropical regions of the world, it was suggested that they may also be suited to the hot and humid conditions of a glasshouse.

In December 1984, a glasshouse of peaches was established at Murray Bridge. A cultivar of a low chilling *Prunus persica* hybrid developed in Florida, U.S.A., was budded onto a nematode-resistant rootstock, 'Nemaguard'. The trees were closely spaced and four main branches were trained from the main stem onto the outer wires of a low, 5-wire T trellis.

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floral development of two peach cultivars 'Maravilha' and 'Flordagold' as well as the nectarine, 'Sunred'. The chilling required by these cultivars is in the range of 275 to 300 hours at temperatures below 7.2°C. This is considerably lower than the 400 to 1000 hours of chilling required by those cultivars presently being grown in southern Australian orchards.

It was hoped that if these trees could be forced to flower and fruit during autumn and winter, then they could be manipulated to fruit at any time of the year, thus giving the grower total control over time of production.

Growth of the trees had been extremely vigorous with shoots extending in all directions, but predominated by strong water shoots reaching to the roof of the house. Shoots were pruned to within 0.5 m of the trellis so that the trees were more managable. This was followed by a more selective pruning during which attention was paid to those shoots most likely to produce flowers, as well as considering the shape and training of the trees. Training involved the bending and laying down of upright shoots to reduce apical dominance and to promote floral initiation and the further development of lateral floral buds. In the case of vigorous trees this practice also promotes the development of spurs capable of fruiting in the following year.

It is well established that defoliation forces the development and bursting of peach buds out of season provided the trees have not entered into the state of true dormancy or rest. During the latter period internal inhibition prevents growth from being induced even if conditions suitable for growth prevail. The effectiveness of chemical and hand defoliation treatments on bud burst were studied. Trials conducted by G. R. Edwards (Priv. Comm.) in the Philippines suggested that 2% zinc sulphate was a suitable defoliant for *Prunus persica*. This was tried as a foliar spray but had no effect. Spraying was repeated with 3½% zinc sulphate but caused no more than 5% leaf-burn. These chemical defoliation treatments were therefore concluded to be unsuccessful. Rather than trying a higher concentration which might have caused twig die-back and splitting of the green bark and would have delayed treatment, thus increasing the likelihood of entering dormancy, it was decided to hand defoliate all trees.

Chemical growth regulators are also known to force bud burst. From work done in Israel and the Philippines, five treatments were chosen and applied 3 days after hand defoliation. The treatments included cyanamide (2% a.i.), potassium nitrate (4%), thiourea (2%), DNC-oil (8%), DNC-oil (8%), followed 7 days later with a mixture of potassium nitrate (4%) plus thiourea (2%), and a control using distilled water. Treatments were applied by dipping three twigs per treatment per tree. These three twigs were chosen to represent the range of shoot orientations and are referred to as: up, horizontal,

and down.

The results obtained from these treatments differed greatly from those expected. Literature stated that potassium nitrate is more effective in forcing floral buds, rather than vegetative buds, to burst. In this study, although it forced more floral buds to burst than any other treatment, it was found to be more effective at forcing vegetative buds. Other variations from expectations were caused by the cyanamide and the two treatments involving DNC-oil. At the concentrations used, all three caused burning of the buds and twigs. Despite these failures the trees recovered and grew vigorously, reaching the roof of the house within 8 weeks of defoliation.

Table 1 shows that only a very small proportion of the buds forced to burst by defoliation were floral, and it was not until these buds developed further that differences in shoot orientations emerged. Not only were there few floral buds present but the proportion of these which actually set fruit was also very low. The 3% on the horizontal shoots represents one fruit set, while the 7% on the downward shoots represents three fruits set. That is a total of four fruits set on the entire 24 experimental trees. The decrease in numbers of reproductive structures with development is due to natural abscission processes and was not unexpected since many flowers were grossly abnormal.

Table 1. Effect of shoot orientation on development and behavior of buds.

		Shoot Orientation		
		up	horizontal	down
Percent of buds which were	Floral	3.3	1.8	2.1
	Vegetative	96.7	98.2	97.9
Percent of floral buds which reached	Full bloom	42	36	55
	Petal Fall	26	19	31
	Fruit Set	0	3	7

Normally, flowers of *Prunus persica* have 5 small green sepals, 5 regular and brightly coloured petals, many stamens and a solitary pistil centred within the receptacle. However, only a few of the flowers present fitted this description. The abnormalities observed were of many types, the most common being large sepals, the presence of two pistils, and the absence of a pistil. In some cases more than one abnormality occurred, as with the frequently observed sterile leafy flower which had 5 large leafy sepals supported on a long pedicel but no petals, stamens, or pistil. Other abnormalities included petalized anthers, several small rudimentary ovaries within a receptacle, and the initiation of two flowers on the one pedicel. Such findings are consistant with the work of other researchers, such as Lloyd and Couvillon (5), where bud burst was forced by defoliation.

Despite difficulties encountered with chemical defoliation and

chemical bud-burst treatments, the growth of peach trees at the most unexpected time of the year and under such unusual environmental conditions has emphasized the importance of the need for different cultural practices in this situation. The main change likely to increase the number of floral buds forced and the proportion which set fruit would be the use of a narrow upright trellis on which the trees could be espaliered. This system might suit the glasshouse situation and the tying down of upright shoots, coupled with early fruiting, could well be an effective way of controlling vigour. It would reduce the competition between long shoots and buds for the available resources, such as carbohydrates and light, thus improving floral initiation and floral development.

Acknowledgement. I wish to thank Mr. Peter Burne, Department of Agriculture, Murray Bridge and Mr. Frank Altamura, Murray Bridge, for their help with this experiment.

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SOIL MICRO-ORGANISMS, PLANT GROWTH AND PLANT HEALTH

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Abstract: Knowledge of the biological processes in growing media is necessary where soils, whether synthetic potting mixes or natural soils, are to be used to produce vigorous, healthy plants. I describe some of these soil processes and also some electron microscope studies of soils which demonstrate the spatial distribution of micro-organisms in soil in relation to roots, clay, sand and organic matter. This paper deals also with soil-borne root diseases which can be devastating to plant health and are a part of the whole scene of soil biology. If soil is considered in this holistic way, control of root diseases through biological control, soil and root modifications, and bark composting will become a reality.

Soil contains a complex of micro-organisms made up of bacteria, fungi, actinomycetes, algae, and protozoa. These micro-organisms are essential for many soil processes involved in plant growth; some micro-organisms are beneficial to plant growth, some are detrimental, and some are neutral. The aim of this paper is to describe some aspects of the ecology of micro-organisms in soil and a number of the soil biological processes which are of interest to plant propagators working with natural soil, modified soils, or soil mixes.

DISTRIBUTION OF MICRO-ORGANISMS IN SOIL

Micro-organisms in soil depend on organic matter for the energy required for their growth and hence most bacteria and fungi are associated with living or dead plant material. As plant roots grow through soil they release sugars, amino acids, gummy polysaccharides and other compounds into the soil around the root making the root-soil interface a zone of intense activity where bacteria and fungi proliferate (28). Such an active population can influence plant health in many ways, e.g. release of nutrients from soil, production of plant growth hormones, biological control of plant pathogenic fungi, and stimulation and attraction of pathogens.

Electron microscope studies of ultra-thin sections of the root-soil interfaces (9) show colonies of different bacteria growing in contact with each other and in contact with the clay minerals, sand particles and particulate organic matter of the soil (Figure 1).

MICRO-ORGANISMS AND SOIL STRUCTURE

Soil micro-organisms play a major part in maintaining and improving soil structure, which is important in providing a

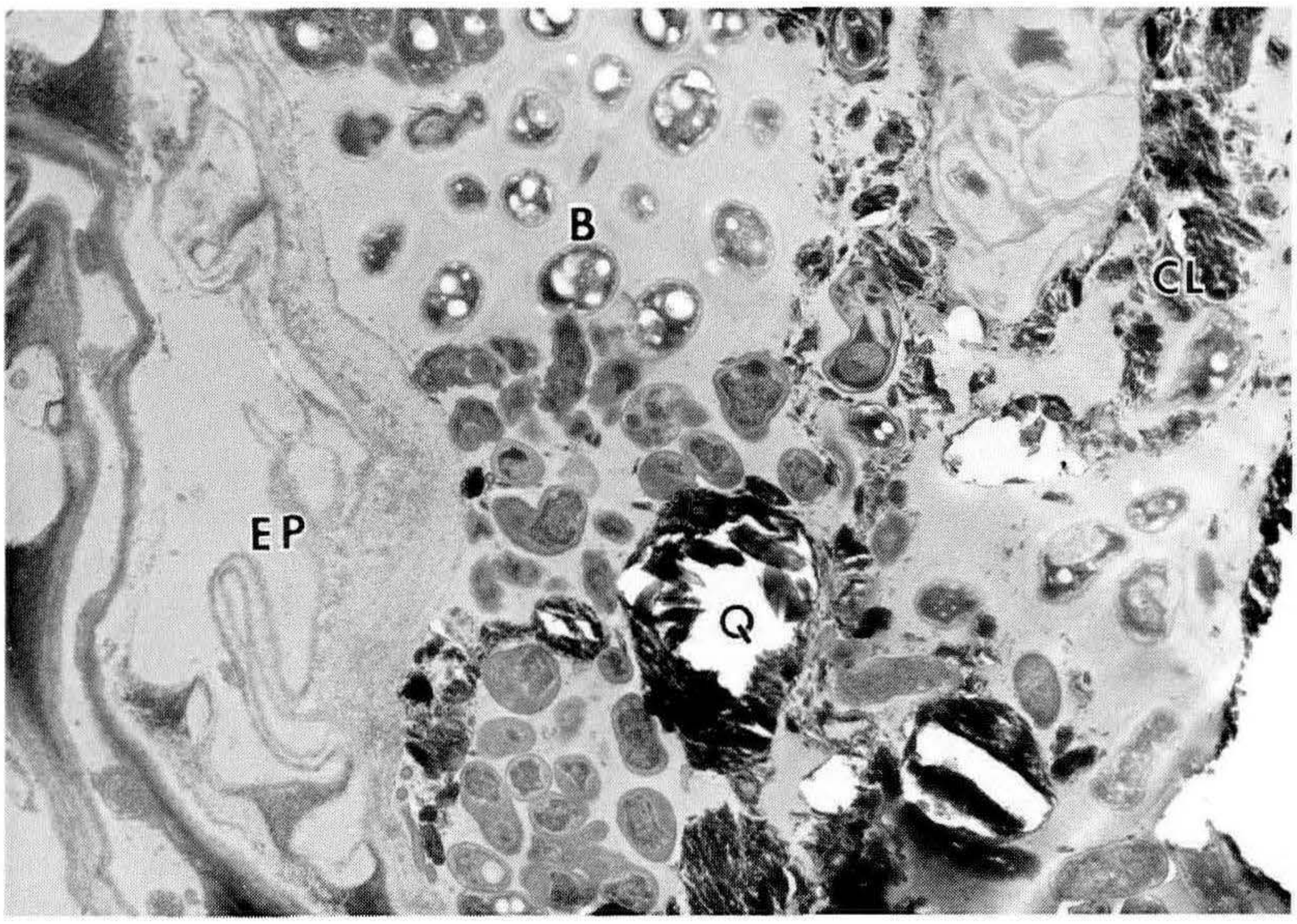

Figure 1. Transmission electron micrograph of a root-soil interface of clover. EP = epidermal cells which are distorted with lysed outer cell walls (cw). B = bacteria. CL = clay. Q = quartz grain. (x6000). Reprinted from: R. C. Foster and A. D. Rovira. The ultrastructure of the rhizosphere of *Trifolium subterraneum* L. in "Microbial Ecology" M. W. Loutiet and J. A. R. Miles, eds 1978. Springer-Verlag, Berlin, Heidelberg.

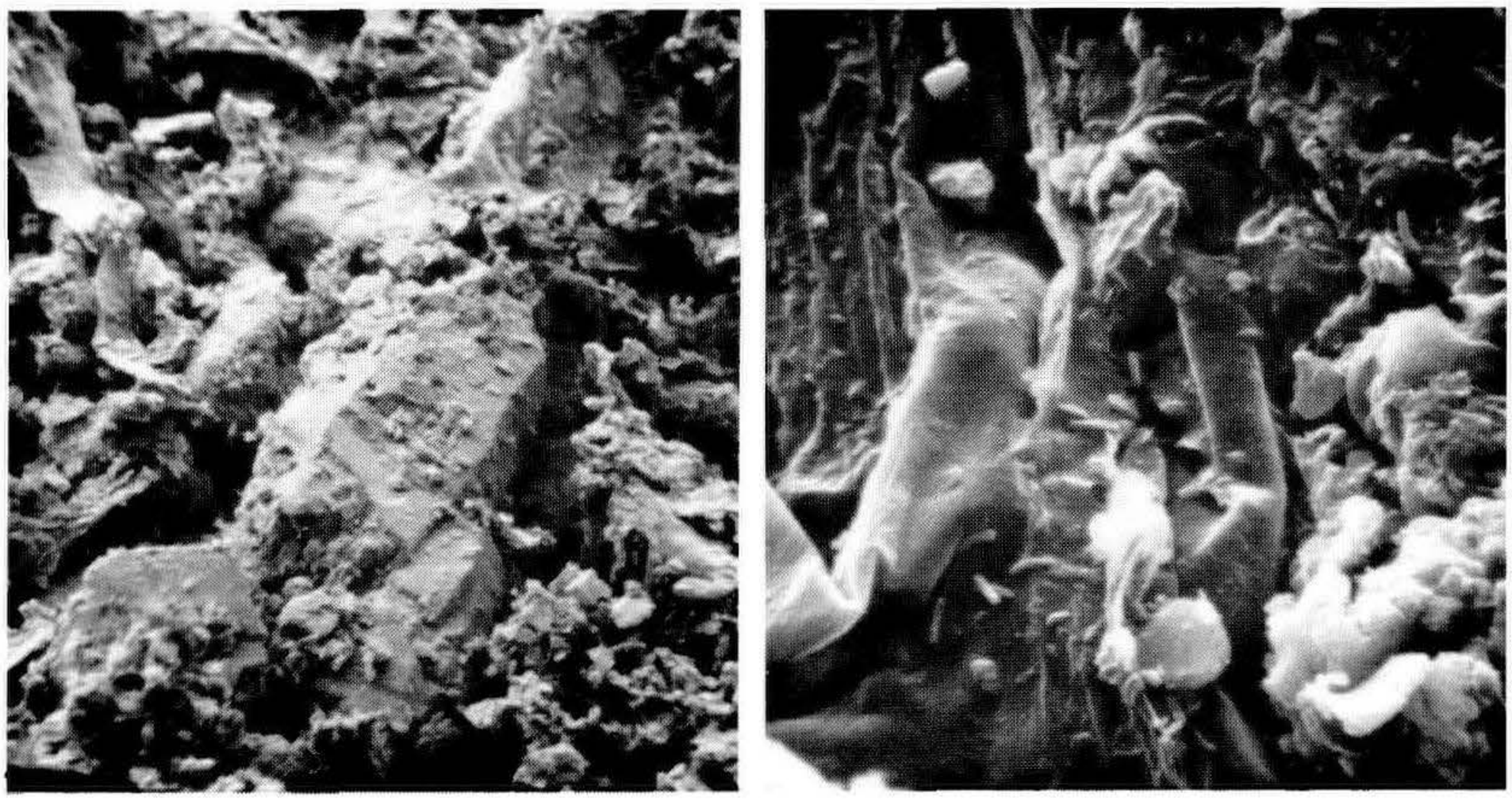

Figure 2. Scanning electron micrograph of roots. A (*Left*). Unwashed wheat root with quartz and clay held to root by the mucigel. (x1000). B (*Right*). Washed clover root surface showing bacteria in mucigel (centre), root hair (left) and clay (right) (x1600). Reprinted from: R. C. Foster, A. D. Rovira and T. W. Cock "Ultrastructure of the root-soil interface". *Amer. Phytopathol. Soc.* St. Paul, Minn. 1983.

favourable environment for plant roots and in reducing soil losses from erosion.

The gummy material, released by plant roots has been called "mucigel" (13). This mucigel plays a vital role in holding together soil aggregates and improving soil structure. Scanning electron micrographs of the root surface shows clay particles and a large quartz grain held together by the mucigel released from the root (Figure 2a) and the mucigel enveloping bacterial cells (Figure 2b).

It is generally found that soil structure is improved more by grass roots than by roots of legumes or crop plants. While much of this structure improvement can be attributed to the fibrous nature of the grass roots and also to the mucigel, recent work has shown that filaments of vesicular-arbuscular mycorrhizal fungi growing out from the roots of grasses play a major part in binding together larger soil aggregates (32). These fungal strands which hold the soil particles together can persist for several months after the grass host for the mycorrhizal fungi has been removed, but soil structure declines with cultivation, the death of these fungi and exposure of soil organic matter to microbial attack.

MICRO-ORGANISMS AND SOIL NITROGEN

Although the bulk of soil nitrogen is in the organic matter, it is mineralized forms, mainly nitrate (NO_3^-) and ammonium (NH_4^+), which are used by plants. The nitrogen cycle (Figure 3) is complex but an understanding of it can help manage the supply of nitrogen available to plants.

Organic nitrogen enters soil either through decomposing plant and animal residues or the fixation (conversion) of gaseous nitrogen to protein nitrogen by free living bacteria, such as *Azotobacter* and *Clostridium*, or through symbiotic associations between plants and bacteria, e.g. legumes and *Rhizobium* or casuarinas and *Frankia*.

The rate of release of mineralized or inorganic nitrogen (nitrate or ammonium) from added residues depends upon the nature and form of the residues. Grass residues are low in nitrogen, and the micro-organisms carrying out the decomposition of such material require extra nitrogen in the decomposition process; this is obtained from the mineral nitrogen in the soil. Legume residues, on the other hand, are high in nitrogen and as they decompose, inorganic nitrogen (which plants use) is released into the soil. However, the rate of release of inorganic nitrogen, i.e. available for uptake by plant roots, is influenced by the nature of the legume residues. Maximum release comes from incorporation of green material but if the residues stay on the soil over summer before incorporation, no mineral nitrogen is released for 60 days after incorporation and, after 110 days, these residues have released less than half the nitrogen released from green legume residues (17).

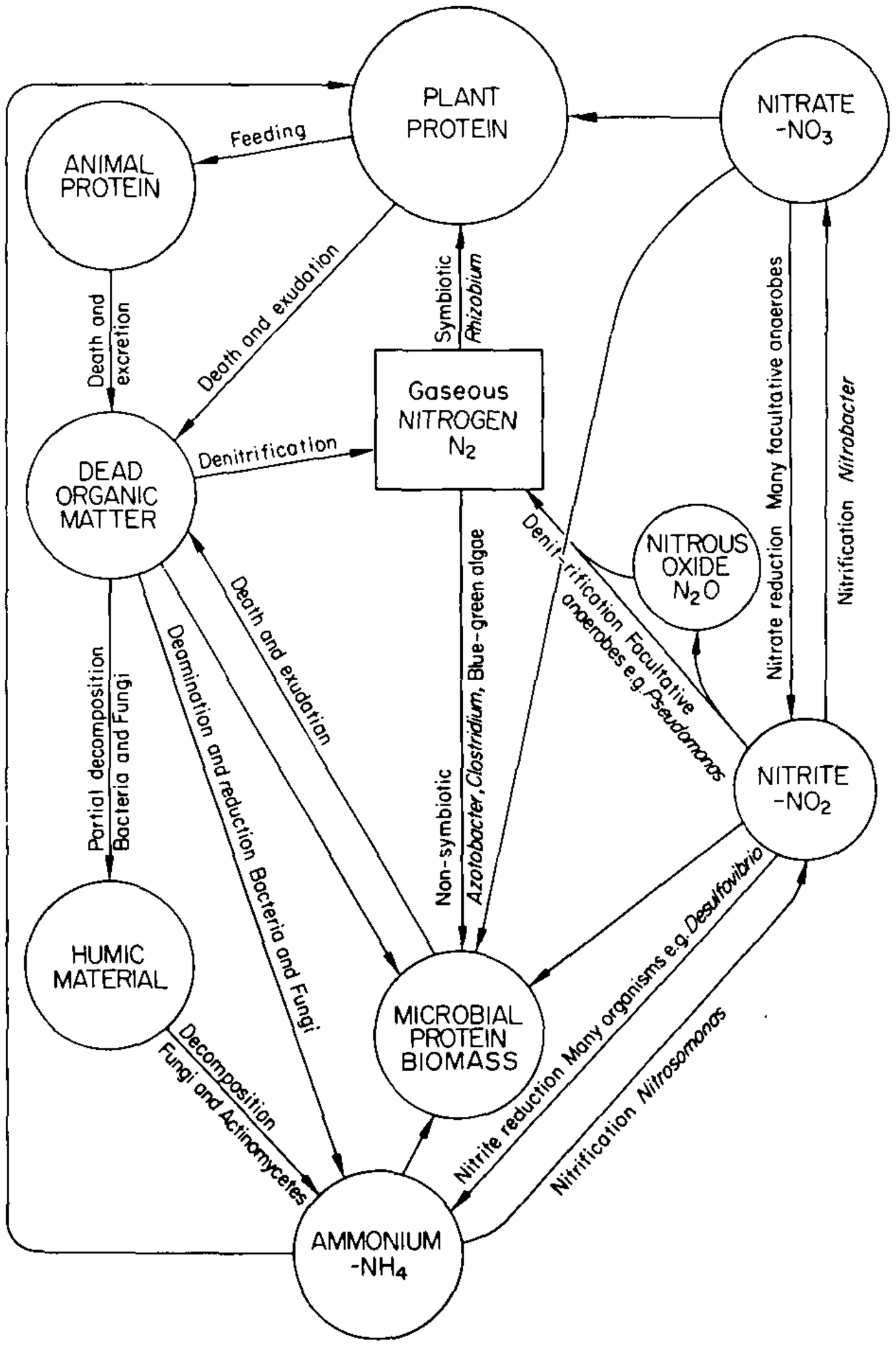

Figure 3. Nitrogen cycle in soil (4).

These results on the release of inorganic nitrogen from legume residues were obtained under the winter rainfall conditions of southern Australia; patterns of nitrogen release differ in different environments, e.g. the rate of breakdown of plant residues in soil doubles for each 8 to 9°C increase in mean annual air temperature (16).

SYMBIOTIC ASSOCIATIONS BETWEEN PLANTS AND SOIL MICRO-ORGANISMS

Mycorrhizal Fungi. These fungi form beneficial symbiotic associations with plant roots and improve plant growth by acting as extensions of the root systems and increasing the uptake of

nutrients such as phosphate and trace elements. The nature of these associations in nursery-grown plants have been reviewed recently (7,19). Mycorrhizal associations form best under low nutrient conditions and their formation may be inhibited by high levels of fertilizer. If such plants with poor mycorrhizas are transplanted to the field with low nutrient levels poor plant growth would be expected. One strategy to prevent this inhibition of mycorrhizal formation in nursery stock is to use slow-release fertilizers (21). The benefits of introducing spores of mycorrhizal fungi into nursery beds of *Pinus radiata* are considerable (Figure 4), e.g. 48 percent and 36 percent increases in growth in fumigated and unfumigated soil, respectively (31).

Figure 4. Response by *Pinus radiata* in fumigated soil to coating of seeds with spores of *Rhizopogon luteolus Left*. Uninoculated. *Right*. Inoculated. Photograph from C. Theodorou, CSIRO Division of Soils.

NITROGEN FIXING MICRO-ORGANISMS

Legume-Rhizobium Association. The benefits of legumes through their nodule formation with the bacterium *Rhizobium* in building up soil nitrogen and thus improving growth of following crops are well known. However, it should be remembered that there are different species of *Rhizobium* for different groups of legumes and that, without the appropriate *Rhizobium*, there is no value in growing legumes for improving soil fertility. Acacias make up an important component of both native forests and ornamental plants in Australia and, as members of the Leguminacae family, form nodules and fix nitrogen with *Rhizobium*, but little research has been done on this association.

Casuarina-Frankia Association. Members of the genus *Casuarina* (common name: she oak) are widespread throughout Australia from foreshore dunes to understories in forests to the arid

interior. A feature of these native Australian trees is that they often grow in extremely poor soils. This is made possible by the associations formed between their roots and two groups of beneficial micro-organisms. The first group is the mycorrhizal fungi which extract phosphate, trace elements, and possibly other nutrients from soil and transfer these to the host plant; the second group is the actinomycetes, known as *Frankia*, which form nodules on the roots and convert atmospheric nitrogen to protein as does *Rhizobium* with legumes.

The importance of these two groups of micro-organisms has been demonstrated by growing *Casuarina* in sterilized soil with low nutrient levels, with and without Frankia and mycorrhizal fungi; when applied separately neither organism increased seedling growth but when applied together growth was increased by 100 percent over the uninoculated control (P. Reddell, CSIRO, pers. comm.). One problem with applying *Frankia* is that, unlike *Rhizobium*, it has proved difficult to isolate and grow in laboratory media and, at present, for most *Casuarina* species crushed nodules taken from the same or a compatible species must be used as inoculum.

Figure 5 illustrates the responses of a single species of *Casuarina* to several frankias. Other studies have shown considerable specificity between different casuarinas and different frankias (27).

Figure 5. Responses by Casuarina *equisetifolia* ssp. *incana* to inoculation with different strains of *Frankia*. C = uninoculated control. Inset—Nodule of *Frankia* nodule from *Casuarina*, 1.5 cm in diameter. Photograph from P. Reddell, CSIRO Division of Soils.

SOIL-BORNE ROOT DISEASES

There is little doubt that soil-borne root diseases caused by bacteria, fungi, and nematodes impose a major constraint on plant production from the favourable environment of plant propagation nurseries to field crops to forests. A brief review of the major soil-borne fungal diseases of ornamentals and standard control methods was presented in these Proceedings in 1980 (18). Knowledge of the biology, ecology, and epidemiology of these root-attacking organisms can help in developing adequate control measures.

Soil pasteurization. Soil pasteurization by fumigation or heat, followed by proper hygiene, is the most effective method of reducing losses from root diseases. In view of the finding in nurseries that *Pythium* spp. and *Rhizoctonia solani* have been isolated from the dust which can be wind-borne and reinfest pasteurized soil in containers (30), the introduction of a form of biological buffering into pasteurized soil appears desirable. This is achieved by heating soil to 60°C for 30 minutes with aerated steam, which destroys pathogens but leaves behind sporing bacteria of the genus *Bacillus,* some of which are antagonistic to fungi and can prevent the rampant growth of chance contaminants (1). Further protection of plants can be achieved if, after pasteurization, the soil is inoculated with bacteria, such as *Bacillus subtilis,* known to suppress pathogens (3).

An alternative method of partially pasteurizing soil to leave behind a residual "buffering" microflora and/or introduce suppressive organisms has been achieved by "solarization"—the process whereby moist soil is covered with transparent polyethlene and exposed to the sun during summer (14). It has been demonstrated that build up of the pathogens, *Verticillium dahliae* and *Fusarium oxysporum* f.sp. *dianthi,* in soil treated by solarization is considerably less than in soil fumigated with methyl bromide (19). The effectivess of this method of partial soil pasteurization has been further improved by introducing the fungus, *Trichoderma harzianum,* which is capable of controlling diseases caused by *Sclerotium rolfsii* and *Rhizoctonia solani* (5).

This form of integrated control of root disease, viz. partial pasteurization, followed by inoculation with a bacterial or fungal culture capable of biological control of chance infestations by pathogens has yet to be used by the Australian nursery and plant propagation industries, despite the fact that much of the pioneering research has been conducted in Australia.

Biological Control of Root Diseases. This topic is far too large for comprehensive treatment in this paper, so readers wishing to gain an insight into many examples of biological control are referred to the excellent treatise on this subject by Cook and Baker (6).

Here I shall describe several examples with particular relevance to the horticultural and nursery industries.

Introduction of Biocontrol Organisms. A major problem on ornamental and tree rootstocks until recently was crown gall caused by *Agrobacterium radiobacter* pv. *tumefasciens*. However, the discovery in South Australia that treatment of seed and roots with a non-pathogenic form of *Agrobacterium radiobacter* (strain K84) protects roots from the pathogen is one of the outstanding successes of biological control (15). The non-pathogenic strain K84 is closely related to the pathogen and occupies wounds on roots and the lower stem, which are the usual entry points for the pathogens. Strain K84 also produces Agrocin 84, an antibiotic to which the crown gall strain is sensitive, and this antibiotic plays a major part is excluding the pathogen. It is now standard practice in most nurseries throughout the world to treat rootstocks of susceptible species with Strain K84. Crown gall control provides an example of how a root pathogen can be controlled by a closely related organism.

The control of *Pythium ultimum,* which is responsible for damping off and seedling blight in nursery plants, has been achieved in greenhouse trials by pelleting seed with a related species, *Pythium oligandrum,* which is parasitic on its pathogenic relative (20).

Biological control of Pythium spp. and *Rhizoctonia solani* has been achieved experimentally by bacteria belonging to the fluorescent psuedomonads. These bacteria protect plants by producing antibiotics toxic to the pathogens—a different antibiotic was found to be responsible for the activity against each pathogen (11,12).

The report (33) that the growth of carnation, stock, zinnia, and sunflower was improved when soil was treated with a plant growth promoting strain of *Pseudomonas fluorescens* (possibly through controlling low grade (minor) root pathogens) shows that such manipulation of the soil microflora offers considerable promise to the nursery industry.

Protection. Cross pollination against *Fusarium* wilt of sweet potato has been achieved by treating tubers with non-pathogenic strains of *Fusarium oxysporum*. This preliminary treatment with the non-pathogenic strain probably causes biochemical changes in the host plant; these changes produce resistance products which are translocated to other plant parts, giving protection against the pathogen (25).

A further example of induced protection was reported recently in California when scientists investigated the mechanism by which a particular cultural practice developed by avocado growers protected trees from *Phytophthora cinnamomi*. This cultural practice consists of interplanting citrus (lime) trees in orchards heavily infested with *P. cinnamomi*. Local growers maintain that this interplanting protects the avocado from *P. cinnamomi* and

improves production. The research has shown that infection of avocado with *Phytophthora parasitica* (a very mild root pathogen of avocado) which would have been introduced into the orchards with the citrus interplanting, induced within the avocado a systemic protection against *P. cinnamomi* (8). The precise factors responsible for such induced resistance are not known, but with further study the application of such a phenomenon to protect trees from certain root diseases may become a nursery practice.

Modification of the Root Environment. Phytophthora cinnamomi is a devastating disease of avocado and damage by this fungus in the wet year of 1974 destroyed 12,000 of the 40,000 avocado trees in Queensland. In 1969, a 30-year-old plantation of healthy avocado trees was found surrounded by heavily diseased plantations. The practice on this healthy plantation was to grow continuous legume-maize cover crops, plus added poultry manure each year together with applications of dolomite limestone to maintain soil pH above 6.0. An investigation of this "Ashburner system" demonstrated that soil from the plantation was highly suppressive against *P. cinnamomi,* whereas soil from surrounding diseased groves were not suppressive (2,26). The suppressive activity survived 60°C for 30 minutes but not 100°C for 30 minutes, indicating that heat-resistance actinomycetes or spore-forming bacteria were responsible but, so far, no single organism isolated from the soil has reproduced the suppressive effect of the whole soil. Two further factors involved in the control of *P. cinnamomi* in this soil are the high levels of calcium and ammonium which result from the green manuring, fowl manure, and dolomite. Such soil treatments are effective on many avocado plantations, especially when combined with the planting of disease-free trees to minimize initial infection.

Root rot and heart rot of pineapples caused by *P. cinnamomi* were serious problems in Queensland, but are now kept under control by applying sulphur to reduce the pH below 3.9. At this low pH zoosporangium formation by the pathogen is reduced and growth of *Trichoderma viride,* which parasitises *P. cinnamomi,* stimulated (26).

The finding in Western Australia that floristically attractive banksias (which are extremely susceptible to *P. cinnamomi*) could be grafted on to a rootstock of *Banksia integrifolia,* resistant to the pathogen (22), offers an alternative strategy for controlling this root disease which is so devastating to the Australian native flower industry.

Bark Composts and Biological Control. Some composted hardwood bark has been demonstrated to suppress *Rhizoctonia solani, Pythium ultimum,* and *Phytophthora cinnamomi* in container media; composted pine wood bark, on the other hand, was not suppressive to R. solani (23,24). This suppression in composted

hardwood bark has been shown to be biological rather than chemical and members of the genus *Trichoderma* are implicated as the major biocontrol agent (24).

A study on barks of Australian trees done in Western Australia demonstrated that composted bark of marri (*Eucalyptus calophylla*) and karri (*E. diversicolor*) reduced root rot in *Banksia grandis* caused by *P. cinnamomi* but did not eliminate the disease (29).

CONCLUSIONS

The aim of this paper has been to demonstrate that growing media such as soils and potting mixes are living systems, with a balance between beneficial and detrimental micro-organisms. Rotation, cultivation, soil treatment, and hygiene are all important in maintaining a desirable balance. Creation of a "biological vacuum" in soil by fumigation or heat sterilization produces an environment in which the chance introduction of a pathogen can create havoc. This can be avoided by treating soils to retain a population which can suppress the chance contaminant. Further inprovement could be obtained by introducing micro-organisms with biocontrol activity.

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A FOGGING SYSTEM FROM SOUND WAVES FOR PLANT PROPAGATION

JOHN GRAY

Tetratheca Native Nursery
Kanmantoo, South Australia

When evaluating methods to improve cutting propagation, the need to overcome the following problems associated with conventional mist propagation became obvious:

(a) Nutrient leaching from the leaves

(b) Cutting media becoming saturated, resulting in decay of cuttings below the surface of the medium

(c) Wide fluctuations in humidity level, especially when misting is done in conjunction with evaporative cooling or fans

(d) High volume of water used

One method of overcoming these problems is to create a fog which will remain suspended in the air. This maintains a very high humidity and reduces transpiration loss from the cutting.

We have found Sonicore nozzles a cost-efficient method of producing fog which produces particles between 3 and 5 microns in size. These nozzles are air-driven acoustic oscillators for atomising water, by passing sound waves through a convergent/divergent section into a resonator cap where it is reflected back to compliment and amplify the primary shockwave.

The result is an intense field of sonic energy focused between the nozzle body and the resonator cap. The liquid pumped into the shock wave is vigorously sheared into minute droplets by the acoustic field.

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The nozzles are self-cleaning and will not clog. Large orifices and low pressures virtually eliminate orifice wear and prevent deterioration of the quality of atomisation, while greatly extending nozzle life. Because of the low water pressures required, considerable savings can be made by using polyethylene piping instead of PVC.

This system allows the desired relative humidity to be accurately maintained. We have ceased using evaporative coolers as a method of preventing transpiration loss in the cutting propagation areas. A higher strike rate of cuttings is being achieved, despite the higher temperatures and sunlight levels being experienced.

Reduced propagation time has resulted in healthier cuttings, making them easier to transplant into the potting medium. Trials we have carried out also indicated that this method was ideal for young plants which had just been deflasked from tissue culture.

The greater efficiency of this fogging system has allowed us to replace 30 conventional misting jets with 3 Sonicore nozzles, which only required two gallons of water each per hour, if they operated constantly under high temperatures. A laboratory-type humidity control was incorporated into the system and this has required little or no adjustment to the fogging system, other than the regular maintenance of the air compressor.

PROBLEMS IN FLORIDA'S CUT FLOWER PRODUCTION

OLE NISSEN

Sunshine State Carnations Inc.
P.O. Box 573
Hobe Sound, Florida, USA 33455

My nursery is located on the southeastern coast of Florida, about 80 miles north of Miami near where the Gulf Stream comes closest to the Florida coast. This provides ideal conditions for the production of our crops.

Our crops include miniature carnations, gerberas, and Asiatic lilies, grown under saw-toothed fibreglass structures, plus snapdragons, delphiniums, and other crops under Saran shade cloth, as well as in the open.

Flowers are shipped to about 350 wholesalers as far west as San Antonio in Texas, and Denver, Colorado, but most are sold along the east coast of the U.S.

Shipments of flowers, mostly by refrigerated truck, begin in October and continue to the end of June each year. All flowers are

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Shipments of flowers, mostly by refrigerated truck, begin in October and continue to the end of June each year. All flowers are

shipped upright in deionised water with floral preservative. All flowers are pre-treated prior to shipping and this is considered of great importance to give the consumer good value.

Florida plays a very important role in the U.S. horticultural scene, leading in foliage production, ahead of California. California is ahead, however, in cut flower production.

Many changes have taken place in Florida's cut flower production since the increase in imports from South America. These come mainly from Colombia and Peru and now account for over 50% of all carnations, miniature carnations, and pompoms sold in the U.S. Over 30% of all roses are also imported and a large increase is expected in the next few years.

Not only are these four being imported, but gerberas, alstroemeria, nerine, lily, gypsophila, and statice are also coming into the country.

This has resulted in many growers going out of production. In my area 12 years ago there were 50 producers of pompoms and chrysanthemums, but now there are only 10 left.

The U.S. growers are greatly worried about this problem, as not only do they have South America to worry about, but the Dutch mounted a serious campaign to capture a section of the U.S. market about five years ago, and are doing substantial business. The Dutch campaign, however, with a very fine advertising campaign to the U.S. retail florist opened the market for many long forgotten flower cultivars.

The U.S. grower, faced with the problems of increased restrictions on chemicals, labour problems, and a general increase in production costs, views these imports with much concern.

Some years ago a campaign was started to prevent imports from entering the country: however, being a small industry the government did not see fit to help. Currently, however, the U.S. rose growers have been successful in achieving a higher levy being placed on imported roses.

Growers of pompoms, carnations, gerberas, and gypsophila, have filed an anti-dumping suit with the Federal Trade Commission, which could result in much higher import duties.

To give you an example of the cost of some imported flowers in Miami, carnations have been sold for extended periods of time at 3 to 4 cents for first quality flowers, miniature carnations for 35 cents a bunch, gerberas for 10 cents a bunch, etc. These prices are below the production costs in the various producing countries.

We, in our business, have tried to take advantage of products not so easily shipped, and products that could be produced in Florida at a time when they would not be available from other areas in good quantity or quality.

RESEARCH INTO PROPAGATION OF AUSTRALIAN NATIVE PLANTS

RICHARD WILLIAMS[1]

Black Hill Native Flora Centre
Athelstone, South Australia

The Black Hill Native Flora Centre was established in the 1970's with the broad aim of promoting the cultivation and conservation of the native flora. This was to be achieved by propagation and research of the State's flora, the establishment of landscaped display gardens and a comprehensive information service, as well as the sale and distribution of a wide range of native plants, particularly those not readily available elsewhere. The research programme aims to bring into cultivation a wide range of the State's native plants, both as an aid to conservation and revegetation programmes and to select and improve species with horticultural potential. To date the work has concentrated on the collection of a wide range of plant material and the development of propagation techniques.

Field Collection. The first step in the research programme is the location and collection of plant material and establishment of a comprehensive seed bank and stock plant collection. At the same time information is collected on the growth characteristics, distribution, and natural environment of each species as a guide to its likely requirements and performance under cultivation. This information, combined with detailed records of nursery propagation trials and observations of plants under cultivation, will provide an extensive information data base on the flora.

Seed Bank. The seed bank at Black Hill contains several thousand lots of seed mostly of known wild origin. All seed is stored in an air conditioned room to prolong its storage life although we do not know the optimum conditions for long-term storage of most species. Ideally, we would test all seed for germination under controlled conditions at the time of collection and then periodically, to determine its viability and shelf-life but staff levels do not permit this. However, we do attempt to grow some plants of each collection, and their germination under nursery conditions is recorded. Where seed germination is found to be difficult more detailed research may be carried out.

Seed germination. Temperature is one factor which may affect germination. Whilst most seed will germinate at around 25°C some require more specific conditions. Of particular interest from species examined to date is the finding that seeds of a number of native species germinate better at lower temperatures, i.e. 15 to 20°C, e.g.

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[1] Senior Research Officer

Myriocephalus stuartii, (Table 1). Some seeds germinate best under fluctuating rather than constant temperatures (e.g. *Helichrysum bracteatum*). Others may enter secondary dormancy if exposed to 30°C or higher, so that they no longer germinate when placed at the lower temperature.

Table 1. Effects of temperature on seed germination.

Temp. deg C	Percent seed germinated (T-50)*		
	Helichrysum bracteatum	*Helipterum humboldtianum*	*Myriocephals stuartii*
Constant			
10	31 (10)	60 (7)	37 (9)
15	35 (6)	55 (5)	63 (6)
20	35 (3)	97 (3)	53 (4)
25	31 (3)	99 (2)	27 (4)
30	19 (3)	93 (2)	33 (4)
35	4 (6)	36 (2)	13 (14)
Alternating 16hr/8hr.			
15/10	51 (7)	53 (8)	51 (7)
20/15	32 (6)	80 (4)	49 (4)
25/20	25 (4)	97 (2)	37 (3)
30/25	19 (3)	97 (2)	27 (4)

*T-50 = number of days to reach half final germination.

These examples highlight the need to consider temperature requirements for routine seed germination. Where seed sowing is usually carried out during spring or summer, it may be advantageous to germinate seeds of some species in a cool place rather than in the open sun where soil temperatures may be far above that required. If sowing time can be managed to coincide with the most suitable temperatures germination will be more uniform and quicker. This could be particularly important for direct sowing, e.g. in the case of bedding plants.

There are many treatments which have been used to stimulate germination of dormant seed: scarification, hot water, chipping, chilling, heating, or firing etc. Often a simple treatment can dramatically affect the rate or percentage of seed germination. The difficulty with native species is simply the diversity of seed germination requirements of different species. Sometimes consideration of their natural environment can give a clue to which treatments might work but often trial and error is the only way. The systematic testing of a wide selection of native species will provide valuable information.

One treatment which has proved effective on species previously difficult to germinate is pretreatment with a gibberellic acid solution (500 ppm). This may be combined with scarification where a hard seed coat is present. Two striking examples are *Ptilotus* and *Epacris* seed which have been difficult to germinate in the past but give near 100% germination following this treatment.

Cutting propagation. It is often desirable to propagate using cuttings rather than seed. The importance of the quality or condition of the cutting material cannot be over-emphasised. This is frequently a problem with wild plant sources. In our programme the aim is to at least get a few plants under cultivation, after which propagation success often improves dramatically. We are also testing a range of treatments in order to find suitable conditions for rooting the wide range of species available.

Responses obtained with rooting hormones vary considerably, not only between concentration and types of hormone but also with the season and condition of the plant material. As a matter of routine, each batch of cuttings in the nursery is subject to a range of hormone treatments in order to detect species and seasonal differences (Table 2). It is not practical to list details of the many species here but to date we have obtained at least 70% rooted cuttings with about half of the species tested. Some species have responded better to particular types of hormone whilst 22% of the species have shown little difference in response.

Table 2. Responses of Australian native plants to rooting hormone applications. (IBA = indolebutyric acid; NAA = naphthaleneacetic acid; NOA = naphthoxyacetic acid).

Treatment ++	Percent of species tested* having	
	>70% rooted	>50% rooted
IBA 1000 ppm	27	47
IBA 500 + NAA 500 ppm	27	47
IBA 500 + NOA 500 ppm	29	45
IBA 1500 + NAA 500 ppm	33	49
At least one treatment	50	68
At least three treatments	22	42

++ 5 second dip in 50% ethanol solution.
* 230 batches of cuttings

We have now changed the range of treatments to include higher concentrations since some species respond to 10,000 ppm or more. By continuing to screen those species which have not yet given at least 70% rooting we will be able to focus on those which require more detailed research to solve propagation problems.

Many factors change within a plant through the seasons of the year, e.g. starch or hormone levels in the shoot, lignification, cambial activity, shoot growth, flowering, etc. These may have a direct effect on the rootability of cuttings. Some are due to the growth cycle of the plants whilst others result directly from the prevailing environmental conditions. As a preliminary study, a number of these plant factors were monitored through the year along with assessment of the rootability of cuttings collected from wild plants.

There was no clear correlation between changes in the factors

studied and the results of rooting trials but a couple of points are worth noting. Firstly, the commonly held view that cuttings should not be taken whilst the plant is in flower is not necessarily valid for the species we worked with. The main period of rootability of cuttings overlapped the flowering period in both *Epacris impressa* and *Ixodia achilleoides*. Secondly, since different species growing at a particular site but having different seasonal growth patterns, may still have similar rooting periods, environmental factors have a direct effect. Periods of higher rootability appear to follow the occurrance of rainfall after a dry spell. These broad observations must be tested over several years or under controlled conditions before definite conclusions may be drawn but they indicate the type of factors to be considered.

Tissue culture applications. The use of tissue culture as a means of propagating plants is commonplace today. We have been developing techniques for native species particularly as an adjunct to the conservation of rare or endangered species but the principles are the same. Generally, the woody native species are more difficult to culture with the culture conditions required often varying among species or even varieties. We have successfully cultured over 20 native species but of more importance is the need to improve the efficiency of establishing new species in culture by determining the critical or limiting factors at each state of the culture cycle.

The pH of the medium, initially and as the cultures progress, has been shown to markedly affect root initiation. One might ask what effect the pH of conventional cutting media has on some species? Also, as with cuttings, the condition of the original plant material may be critical in establishment of tissue cultures as demonstrated by *Epacris impressa*. This species proved elusive in culture until suitable material was obtained from pretreated stock plants. Fresh growth was included by increased nitrogen and pruning of plants grown in the glasshouse. A similar response has been obtained with *Astroloma humifusum*, another difficult species from the same family.

The transfer of plants out of culture into potting media is often a critical stage. We are investigating the pretreatment of plants in culture to improve the success at this stage. The type of roots produced in culture affects plantlet survival. Different hormone treatments may all induce roots but root morphology can vary and thereby affect survival. Another aspect is the susceptability of leaves to desiccation. By reducing humidity in the culture tube for a period prior to transplanting, either by changing the osmotic potential of the medium or by loosening the cover on the tube, the plantlets may be hardened in culture. Exposure of plants to higher light intensity and reducing the sucrose level in the medium may promote photosynthetic activity. These refinements of technique will each contribute to the efficiency of tissue culture propagation.

Most work on plant tissue culture is centred on vegetative propagation but *in vitro* techniques can also be applied to aspects of seed propagation. Some techniques which have practical applications include immature seed or embryo culture and in-vitro pollination of incompatible species.

Stock Plants. As mentioned above, the condition of the plant material used for both conventional cuttings and tissue culture is important. Where stock plants are held under cultivation appropriate management of the plants can greatly increase the yield and rootability of cuttings. Having established a wide selection of species in containers we are examining the effects of nutrition, water regime, and regular pruning on the yield of cutting material. Other practices to be considered are the application of plant hormones or growth regulators and the control of light levels to precondition the shoots for improved root initiation on cuttings or shoot multiplication in culture.

Conclusions. Many species of our native flora have potential for cultivation either as landscape plants or as commercial crops, others need to be cultivated for conservation purposes. The Black Hill Native Flora Centre programme is introducing a wide range of species into cultivation and researching improved propagation techniques. Plants with particular merits can then be selected for further research into their cultural requirements and development for commercial production. This research programme, combined with the promotion of public understanding and appreciation of the flora, should benefit both the conservation of our natural vegetation and the expansion of horticultural utilisation of native species.

PLANT PROPAGATION IN CHINA

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Plant propagation in China is done at a basic level by the predominantly peasant population, without the aid of modern technology or the sophisticated equipment that money can buy.

Climatically and geographically China is a land full of surprises. Areas where plants are cultivated range from the permanently frozen tundra in the north to fully tropical zones in the south. China is much larger in area than the whole of Australia, measuring over 5000 km from east to west and more than 5500 km north to south.

In the far west is the Tibetan plateau which remains cold all year. Mountains fill about 33 percent of the Chinese landscape and, because of the rainfall experienced in these mountainous regions, there is a very large number of river systems spreading across the land. One of these, the Chanjiang (Yangtze) River, is the fourth longest river in the world—covering some 6000 km. There are other major rivers such as the Huang He (Yellow) River, and hundreds of smaller ones as well as myriads of lakes.

In contrast to this there is the huge inland Gobi Desert which is bare and desolate. At the edge of the desert is an area called Turpan, which is a huge depression that is actually 150 m below sea level and is one of the lowest, hottest, driest places on our planet.

Arable farming land in China is very limited and is estimated to be no more than 0.1 ha. per head of population. All the useable land is farmed and utilized to obtain maximum output by integrating and interplanting horticultural and agricultural crops. In many areas four to five crops can be seen growing together in one plot of land.

Trees are planted everywhere. Vast areas are being reforested, every railway line and roadway has millions of trees planted along the verge, mainly poplars, willows, conifers, paulownia, and eucalypts from Australia.

These agroforestry projects supply wood for fuel, carpentry, building, and some is exported to Japan for the production of consumer items.

For century after century the people of China have propagated and grown plants just to feed themselves, operating as self-sufficient family groups or in communes. One of the results of some 2000 to 3000 years of peasant farming in communes or small communities has been the development of relatively isolated farming areas similar to counties or small state provinces.

[1] Horticultural Advisor

These individual areas have gradually developed their own selections of plants and vegetables. This factor, coupled with the tremendous diversification of crops which has arisen from this practice has resulted in a fantastic genetic pool, from which the rest of the world will benefit.

For instance, there are about 200 species of vegetables grown in China. Recent research has shown that these plants belong to 29 family groups and a staggering 11,000 selections (cultivars) have been found.

The diversification of species does not only apply to food and forestry plants. There are many plant selections (occurring in the wild) or growing in botanical gardens, such as conifers, rhododendrons, azaleas, magnolias, and herbs. Many of these selections could have a role as garden plants, ornamentals, forestry trees, or in plant breeding programmes.

The recent development (1980's) of the "responsibility system" has allowed farmers/growers to control small plots of land and to produce what they like. This land has virtually become a hobby farm within the commune system. Family enterprises conducted on this land are separate from the commune system and money gained by sale of products from this land is almost tax free.

In this type of climate many Chinese are actively engaged in propagating plants and trees to sell, and so increase their income. Propagation is usually by seed, cuttings, or division in open ground. Cheaply built structures made from bamboo and plastic sheeting are used as "greenhouses" (Fig. 1). Plastic sheeting is used very extensively to aid in propagation; in fact the use of plastic is one major reason that horticultural and agricultural production has increased fivefold in the past few years. This is due mainly to the crop protection provided.

Figure 1. An example of the extensive use of plastic sheeting in crop production in China

Some large tree nurseries exist in China but most of the propagation is done in individual family units within a commune. There are 21 botanical gardens in China. The gardens visited were being upgraded and in some cases re-landscaped. Because of the past neglect and lack of funds, due to severe restraints before the cultural revolution, these institutions are also in need of modern propagation techniques, advice, and technology. Many large city parks or areas planted with ornamental trees and shrubs also have small plant propagation nurseries attached (Fig. 2).

Figure 2. Small propagation nursery attached to an arboretum. Cracked silt layer from bottom of dried-out fish production pond has been used as a fertiliser.

The "China" that is developing under the new socialist/capitalist system is benefiting the Chinese people. Now they have a sense of importance, renewed energy and incentive, and have more money to buy consumer goods and farm equipment.

Although I have visited China for three consecutive years it was only in 1986 that I saw the first evidence of plant nurseries developing, probably on land controlled by the family groups. Nearly every family home in China has potted plants on display, so the market demand is there to be exploited. I estimate that the ornamental plant industry, flower growing industry, and other related horticultural industries will develop within China during the next decade. In fact, because of the cheap labour available and present government incentives, I would not be surprised to see China make unprecedented advances in horticulture and become one of the leading producers in the world (Figures 1, 2, 3, 4). An excellent example of China's ability to jump the industrial, technological gap

is the building of a huge hydroponic factory in Beijing where more than 20 vegetable cultivars are grown in a multi-layered tiered system.

Figure 3. Typical plant transport system using a bicycle.

Figure 4. Grass matting used for frost and snow protection in vegetable plot.

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CLEAN PROPAGATING MATERIAL

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Following the publication by Kenneth F. Baker of "The U.C. System for Producing Healthy Container Grown Plants" (1), plant propagators have introduced various techniques to treat growing media to eliminate diseases and pests. The pasteurisation of growing media has resulted in improved profitability of propagation enterprises and a healthier product for the consumer.

However, it is evident from requests to import propagation material from overseas, that many plant propagators, fanciers, or plant breeders are unaware of the advantages of clean propagating material.

Advantages of Clean Propagating Material

—Reduction of "nesting" diseases in propagating benches, e.g. water-borne diseases—*Pythium, Phytophthora, Fusarium,* and *Verticillium.*
—Reduction in foliage diseases, e.g. mildews, rusts.
—Improvement in "bud-take" with use of virus-tested budwood, e.g. prune dwarf virus and *Prunus* necrotic ringspot virus-tested peach budwood.
—Better plant growth using virus-tested budwood, e.g. cherry nursery plants free of pollen-borne viruses.
—Improved nursery productivity through:

lower rejection rate	greater throughput
lower spraying costs	production of quality product
less consumer complaints	

Disease/Pest Risk level of Propagating Material

Tissue Culture	increasing risk
Seed propagation	of introducing
Budding	diseases and pests.
Grafting	
Cuttings	
Bulbs, corms, rhizomes	
Rooted plants	

Tissue Cultures:
Contamination from:
—Bacteria/fungi/nematode/virus/mycoplasma/insects.
Decontamination by:
—Reculturing

Prevention:
—Hygiene in operations
—use of disease-screened mother stocks to eliminate virus/viroid/mycoplasma diseases.

Seed propagation:
Contamination from:
—trash
—seed coats—rusts/smuts/tobacco mosaic virus
—foreign seeds—weeds
—internal—seed-borne viruses (lettuce mosaic, pea seedborne, prune dwarf, prunus necrotic ringspot) fungal smuts and bunts.
Contamination Control:
—Immersion in hot water (temperature and exposure time dependant on species).
—aerated steam (temperature and exposure time dependant on species).
—chemical dips (bacteriacides (streptomycin, sodium hypochlorite).
—fumigation, (methyl bromide for insects).
—Screening (removal of weed seeds).
Prevention:
—Use of certified seed

Budding/Grafting/Cuttings
The difference in disease/pest risk between buds and graftwood is the number of contaminants per unit propagule.
Contamination:
Surface—bacteria/fungi/nematode/insects
Internal—bacteria/fungi/nematode/virus/mycoplasma.
Decontamination:
—Chemical dips—fungicide/bacteriocides/insecticides
—Fumigation—methyl bromide for insects
—Immersion in hot water
Prevention:
—Routine hygiene programme to reduce disease/pest levels on stock plants.
—Disease screening of stock plants (elimination of virus/viroid/mycoplasma diseases).
—Isolation of stock plants to reduce pest/disease contamination.

Bulbs/Corms/Rhizomes:
Additional contamination from soil-borne pests and diseases.
Contamination from:
Surface—aerial and soil-borne bacteria and fungi, insects/nematodes.
Internal—bacteria/fungi/nematode/virus/mycoplasma

Decontamination:
—Hot water treatment (temperature and exposure time dependant on species)
—Chemical dips—insecticides/fungicides
—Fumigation—insect control

Prevention::
—Routine hygiene programme to reduce pest/disease levels on stock plants.
—Disease screenings of stock plants (elimination of virus/viroid/mycoplasma diseases).
—Containerisation to reduce soil borne pests/diseases
—Isolation of stock plants to reduce pest/disease contamination

Rooted Plants:

Contamination:
—Surface—aerial and soil borne bacteria and
—Fungi/insects/nematodes
—Internal—bacteria/fungi/nematode/virus/mycoplasma

Decontamination:
—Soil removal
—Chemical treatment—fungicide/insecticide
—Fumigation—methylbromide

Prevention:
—Plants from accredited programmes, e.g. Avocado Nursery Voluntary Accreditation Scheme
—Routine hygiene programme to reduce pest/disease levels in stock plants
—Disease screening of stock plants
—Isolation of stock plants

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APPLICATION OF IN-VITRO POLLINATION AND EMBRYO CULTURE TO AUSTRALIAN NATIVE PLANTS

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Whilst for horticultural plants it is desirable to use vegetative propagation to maintain genetic uniformity, there are times when genetic diversity is desirable, e.g. in plant breeding and selection programmes, or for conservation of species diversity. However, not all plants set viable seed and, in other cases, seed is damaged by insects or released from the plant before it can be collected. Hybrids often do not produce seed, either because of pollen incompatability or because of embryo abortion during seed development. Under these circumstances some means of artificial seed production could be valuable. At the Black Hill Native Flora Centre we have been developing the application of *in-vitro* techniques to such situations.

In-vitro studies of pollination and seed development may also shed light on problems which may ultimately be overcome by more conventional techniques once we understand the problem.

This paper presents examples of the application of *in-vitro* techniques to the conservation of the rare native species, *Swainsona laxa*, and the artificial ripening of *Acacia* seed. Other practical applications will be discussed.

In-vitro pollination. The case example is *Swainsona laxa*, a native legume on the brink of extinction. At the time of this work no wild or cultivated plants were known to exist; all we had were a few stored seed. These seed produced three plants which flowered but did not set seed. This was critical because the species is essentially an annual and, therefore, is dependent on seed production for survival of the species. An urgent investigation began.

The simplest hypothesis was that the flowers were not producing viable pollen. We collected pollen from the open flowers and tested it on agar plates in the laboratory. It did not grow. Since pollen often has a short life span after it is shed more samples were collected just as flowers were opening, i.e. at the first opportunity for cross pollination. Again the pollen did not grow on the agar plates. To establish whether the problem was one of infertile pollen production or of short-lived pollen we dissected flower buds at a stage well before flower opening and tested pollen from this stage. This time the pollen did grow on the agar.

We now have the situation where viable pollen is produced at the bud stage but loses its viability before natural cross-pollination can occur—hence the lack of seed set. But what about self-pollination? Most papilionaceous (pea-flowered) species are self-

fertile. Since we had shown that viable pollen was produced, the flowers of *Swainsona laxa* must be self-incompatible.

A common form of self-incompatability is caused by a deleterious interaction between the pollen grains and the stigmatic surface on which they must germinate to effect fertilization. We wished to see if pollen known to be viable in the laboratory would germinate and produce a pollen tube in the stigma of the flower. This can be observed using fluorescence microscopy and suitable botanical stains. With this technique pollen tubes can be clearly distinguished in stigmas squashed on a microscope slide. We applied the technique and found that no pollen grains grew on the stigmas of *Swainsona* even though we knew they were viable in the laboratory. The point of incompatability was established.

Our next problem was to overcome this incompatability in order to produce seed. First we developed a method of dissecting pistils (the female part of the flower including the stigma and ovary) from flower buds and culturing them on agar in a test tube. This made it more easy to control the process. We then decapitated the pistils to remove the stigma and applied fresh, viable pollen to the remaining explant. The ovaries on these pistils soon began to grow and eventually produced viable seed. The immediate problem of saving the species was solved.

From the above research we now understood why the *Swainsona* plants were not setting seed and we could bypass the problem in the laboratory. However, another approach remained to be explored. Natural cross-pollination was prevented by the lack of viable pollen from open flowers. Was the self-incompatability at the stigma a general response or confined to self-pollination within the same flower? What if viable pollen collected from buds was applied to other open flowers on the plant? We carried out hand cross-pollination of plants in the glasshouse using pollen collected from buds and again obtained seed set. Thus the lack of cross-pollination was due to the lack of a source of viable pollen, and the incompatability was confined to within individual flowers. This hand cross-pollination approach is much more practical than *in vitro* culture and has now been used to produce many seed.

While this example of preserving a rare species is a special case, the same techniques could have wider application. In-vitro culture of pistils offers a useful research tool for the study of pollination biology of other species. It could also be useful where controlled pollination is required in a plant breeding program. Pistils could be collected well before natural pollination occurs thereby avoiding uncontrolled pollination. Where desirable crosses are prevented by incompatability arising at the stigma, decapitation and pollination of cultured pistils may be the solution. In this way these techniques could play a practical role in the development of new cultivars of horticultural plants.

Embryo or immature seed culture. Acacias, along with many other native species, often release their seed soon after it matures, usually after a burst of hot weather. This makes the collection of mature seed difficult unless the plants are watched closely. On the other hand if seed is collected before it matures it may not germinate. We face this problem when trying to propagate species of wild plants from remote areas. Embryo or immature seed culture can provide the solution.

Green (immature) seed pods are present on plants over a relatively long period of time, therefore it is not necessary to be there at just the right time. The earlier the collection the less developed will be the embryos or seed within the pod. It is possible to extract these embryos or immature seed and culture them on suitable media so that they complete their development. Depending on the culture conditions and the stage of development of the embryos, one may get the embryos developing and growing directly into plants, or mature seed may be produced. Plants can be propagated either way.

The development of mature seed in culture is of particular interest. We have shown that immature but well developed seed can readily be brought to maturity in the laboratory, then dried and stored as normal seed for later sowing. This technique could be of practical benefit because it should be possible to use bulk liquid cultures for mass production. Given appropriate culture conditions this may be a way of producing high quality seed of some species.

Where embryos are collected at a very immature stage a more complex medium may be required. It is also more likely that the embryos will grow into plants rather than forming seed. This makes handling of the plants more difficult and they need to be grown-on directly rather than stored as seed. However, it may be possible to establish suitable conditions for suspension of embryo growth to permit their storage until required.

Embryo culture may also be used for plant breeding. Sometimes certain crosses result in successful pollination and fertilization but the embryos abort early in their development. It may be possible to extract and culture these embryos to maturity.

Another exciting possibility is the creation of artificial seed. Whether embryos are produced as suggested above or are produced through tissue culture involving somatic embryogenesis, it may be possible to provide an artificial coat enclosing individual embryos with a small quantity of nutrient medium thereby creating an artificial seed. Such a development would open the way for economic mass production of cultured seed for field crops where more conventional tissue culture is uneconomic.

Conclusions. The actual examples discussed above are part of our research to solve specific problems of native plants but it should be clear that there is considerable potential for the broader applica-

tion of the techniques being developed. Much of the technology referred to will only be used by the specialist but I hope I have helped make you aware of the possibilities. You might also be able to see other potential applications of relevence to your particular area of interest.

SALINITY MEASUREMENTS IN POTTING MEDIA

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One of the most common problems encountered in nurseries is salinity, although the grower is often not aware of it. Excessive salinity may be the result of over-fertilization, combined with lack of leaching, and/or high levels of salts in the water supply. It will dramatically reduce growth rates, often before there are any visible symptoms. Low levels of soluble salts in the potting mix can also be a useful indicator of fertilizer deficiency.

The salt level in pots may also change rapidly, even on a daily basis. For example, in heat-wave conditions there may be rapid fertilizer release from controlled-release fertilizers, especially if it has been recently applied. A single heavy watering can also dramatically reduce the salt level. Since salinity readings can be "out of date" quickly, measurement at the actual nursery is very desirable.

A number of techniques for measuring the salinity of potting media are being evaluated by the Department. The techniques are:

(a) *Saturated paste extract method* (SP). This is a widely used standard technique. A paste is made of the potting medium, the water is extracted under vacuum and the electrical conductivity (EC) of the solution is measured. This technique is time consuming, requires specialised equipment, and may not be suitable for very coarse potting media.

(b) 1:1.5 medium/water dilution technique (1:1.5). Moist potting medium is mixed with 1.5 times its own volume of water. The EC of this slurry is then measured. Because of its simplicity this technique is gaining in popularity and gives reasonable results. However, it does not take into account fully the bulk density of the media.

(c) *1:5 medium/water dilution technique* (1:5). Potting medium is mixed with 5 times its weight of water. The

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(c) *1:5 medium/water dilution technique* (1:5). Potting medium is mixed with 5 times its weight of water. The

electrical conductivity (EC) of the solution is then measured. This technique is more suited to mineral soils as it does not take into account the water holding capacity of the media.

(d) *Pour-through technique* (PT). This is a simple and recently developed non-destructive technique which can be used directly on plants growing in pots. Water is added to the surface of the potting medium. The leachate is then collected (about 100 ml) and its EC measured.

The problems associated with the interpretation of the results of dilution techniques (1:1.5 and 1:5) have been pointed out by many workers. These techniques do not take into account fully the water holding capacity of the medium and, in the case of the 1:5 technique, the variation in bulk density among media makes it difficult to interpret results. This places serious restrictions on their use in determining salt levels in potting media. The use of the SP and the simpler PT technique would thus appear to be preferred.

Table 1 illustrates the difficulties involved in comparing results among techniques. The saturated paste technique is considered by many to best represent the salt level in the potting medium because its use minimises differences in bulk density and water holding capacity. However, when it is used to measure salt levels in soils of varying clay content, a "conversion factor" based on clay content is usually used to determine if the salt level in the soil is excessive.

Table 1. *Salinity measurements in various potting media. Measurement is by* electrical conductivity (μS).

Medium	Method used			
	1:5	1:1.5	S P	P T
(a) sawdust, peat, pinebark, sand (1:1:1)	239	640	1260	1456
(b) peat, sand (1:1)	263	953	2558	3720
(c) peat, pinebark, perlite (2:1:1)	671	1047	1863	1842
(d) peat, perlite (1:1)	741	961	1950	1912
(e) peat, ricehulls, sand (2:1:1)	364	1012	2332	2737

l.s.d. = 288

Similar conversion factors may also be necessary for its use with potting media. In three of the five media in Table 1 there was no significant difference in salt level as determined by the SP or PT method. However, in the other two media the PT method gave significantly higher readings. Because the PT technique tends to displace the medium solution rather than dilute it, it may more accurately reflect the salinity level in the medium as perceived by the plant. The reason(s) for the variation between the PT and SP techniques for the different potting media is being investigated. It

has been demonstrated that the difference is not simply due to dilution with inert components (e.g. sand). The effect of the properties of the organic components on the difference between the two techniques is now being investigated.

At present, no standards exist for interpretation of the PT technique results. However, because of the wide ranges allowed, the existing SP standards (Table 2) may be used, with care, to interpret the PT results.

In conclusion the pour-through technique would appear to offer nurserymen a quick and simple method for determining the level of salinity in their nursery growing media.

Table 2. Interpretation of conductivity readings, based upon saturated paste extracts (μS).

Plant tolerance	Desirable range (μS)
Low	1000–2000
Medium	2000–4000
High	4000–6000

(After Bunt, 1976). Note, this a general guide only.

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PROPAGATION AND DEVELOPMENT OF SOME NEW FRUIT AND NUT CROPS FOR SOUTHERN AUSTRALIA

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Many horticulturists would argue for the development of crops in areas that seem most suited to the growing requirements of the species in question. Thus, it is thought that avocados should be grown in Queensland, almonds on the Adelaide Plains, and pistachios in the Murray Valley. In general this tends to be the way things are, and so it should be.

Certain aspects of the fruit and nut market however, encourage the spread of crops into areas where their presence may be considered unusual. For example avocados in the Adelaide area. Avocados are not produced in any quantity or quality in Queensland in January or February, and in these months prices rise sharply as a result. Avocados grown in the Adelaide area are harvested later, and can supply fruit during this period. The high prices obtained compensate for the increased production costs and lower yield.

Producers of unusual fruits and nuts can take advantage of the special interest generated by their produce locally grown. There are several examples of crops whose normal range has been extended due to these market factors, and nurserymen who have attempted to tap this potential.

CLIMATIC FACTORS

Adelaide, in South Australia, seems to have a climate which is suitable for a wide range of tree crops. These include almonds, avocados, stone fruits, pome fruits, citrus, mango, guava, carob, pistachio, pecan, and quandong.

The largely frost-free winter enables almond flowers to set while avocados and mangoes comfortably survive the cold. There is enough cold weather however, to provide the chilling required for pistachios, pome and stone fruit. The good winter rains flush salts from the soil, which have built up during summer irrigation.

The moderately long warm summer provides enough heat to mature the guava, pistachio, and pecan. The low summer rainfall and humidity tends to limit fungal diseases associated with areas with a summer rainfall and high humidity. Carob, pistachio, and quandong do well free from these diseases.

It has been found that with irrigation and the use of wind breaks that a wide range of tree crops grow very well in this area.

PROPAGATION

The traditional in-ground propagation of trees was not used in our nursery. Systems for growing all species in containers have been developed. Growing plants in containers removes many of the constraints of field-grown plants and has many benefits:

(a) Plants can be grown in disease-free soil-less media

(b) Plants can be moved from one environment to another to maximise growth rates

(c) Operations such as potting, moving, selling, or planting-out can be undertaken at any time.

Several innovations in propagation practices have occurred in our container-based nursery. Some of these are:

Avocados. Seed is collected in early winter (June) and heat-treated to remove possible infection with *Phytophthora cinnamomi*. They are planted into milk cartons in a light soil-less mix.

Seeds germinate evenly over-winter in an igloo and grow to grafting size by late spring. Grafting may occur at any time after this.

A whip graft is used. Grafting is usually done during a cool spell. The plants are then placed under shade for growing on. These grafted plants have established a reasonable top growth by winter and are potted-on in spring. They are grown-on under shade until they are ready for sale.

All avocados produced for commercial growers are grown in sterile soil-less mix, and raised on benches. This is to avoid infection by root-rot fungi.

Botrytis and light-brown apple moth are two consistent pests during high growth periods and must be controlled with regular sprays.

Pistachio. Field-grown trees are notoriously difficult to transplant so container-grown plants are essential.

Seeds are germinated in winter and plants reach graftable size the following winter. They are whip-grafted in winter and grow away strongly in a spring flush of growth which can be from 10 to 30 cm long. This growth hardens off in December at which time they may be planted.

Some trees will make an autumn flush of growth which may make a total growth of about 40 to 50 cm. The best planting time is from April to September.

This system of propagation relies on the slow growth of callus tissue over winter at temperatures with a typical daily range of 7 to 14°C.

Quandong. Seeds are germinated using the CSIRO technique (1). The seedlings are planted into pots when the roots are 4 to 10 cm long. Quandong, *Fusanus* spp. or *Santalum* spp., is a partial root

parasite so the host plant needs to be planted in the same container when the seedling is about 10 cm high. Gazania, lucerne, and strawberry clover have all been used successfully as host plants. Several trimmings are required to keep the host plant under control.

Seedlings can be planted out after 6 to 12 months, preferab1y in late autumn or early winter. Plants should not be over-watered and can be susceptible to "wet feet" in heavy soil. Many seedlings will bear 4 to 6 years after planting.

The future development of a commercial quandong fruit industry depends on the discovery of fruit types that have desirable marketing factors.

There is a high variability among field populations so an efficient clonal propagation system is needed. This will also allow the large numbers of trees needed for a commercial-sized planting. CSIRO has reported some success in this regard.

Chestnut. The Spanish chestnut is a temperate climate crop with good market potential. It is, however, very sensitive to root diseases, especially *Phytophthora* spp. There is a danger that these root diseases may be transmitted by field-grown plants from infected nursery soils and, as with avocados, growers must be confident that they have not planted infected trees.

Chestnuts are grown in containers in sterile soil in the nursery to ensure they are free of root diseases. The propagation methods are the same as for avocados, i.e. the seeds are heat-treated, germinated in sterile media, potted up into treated potting mix and grown ready for grafting.

A whip graft is made using dormant, cold-stored graft wood. Careful follow-up nursery culture results in strong growth and a tree that is ideal for planting out in autumn.

The compact fibrous root system produced in the container enables good field establishment without losses due to poor root initiation sometimes associated with larger field grown trees.

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REPLACING THE BIRD: POLLINATION IN THE GENUS STRELITZIA—MAINLY S. REGINAE

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This may appear an unusual title, but I hope the title will become self-explanatory. Some 20 years ago I became interested in producing *Strelitzia reginae* as a plant for the small container market. The normal method of propagation by rhizome division was out of the question due to the large size of the divisions and the high cost of this method. It was decided to try propagation by seed. At this time seed was available mainly from overseas suppliers and cost approximately 3 to 4 cents a seed. After some rather costly and poor germination results with commercial seed I decided to try and produce my own. At this stage I went to the horticultural literature to further study the genus *Strelitzia*.

Description of the genus:

The genus *Strelitzia* was named in honour of the queen of George III of England—Charlotte of Mechlenburg of Strelitz in Germany. This South African genus in the family Musaceae has four species of large perennial herbs with a rhizome or with a woody trunk. Leaves are large, long-stalked, in 2 ranks. Scape is terminal, or in upper leaf-axils, shortly exserted from the leaf-sheaths; bracts 1 or 2, large, boat-shaped, slender-pointed, more or less coloured. Flowers are large, sepals free, long, keeled; petals very dissimilar; stamens 5; ovary 3-celled. Fruit is a leathery, many seeded capsule.

Key to the species (1)

A	Stem not elongated, flowers yellow-blue	B
AA	Stem tall, flowers white-blue	C
B	Leaves ovate or ovate oblong to lanceolate, *S. reginae*	
BB	Leaves bladeless or nearly so, *S. reginae* var. *juncea*	
C	Base of leaves cordate, inner flower segments white, *S. alba*	
CC	Base of leaves obtuse, inner flower segments blue, *S. nicolai*	

S. alba {syn. *S. augusta*}. Stem short. l.-stalk about 6 ft. long, blade about 3 ft. long, shining green. Spathe purple; outer fl.-segs. white, inner white, unequal, very short. March. 1791.

S. nicolai. Stem up to 15 ft. h. l.similar to *S. alba* except that base of blade is obtuse. Spathe chestnut-red, outer fl.-segs. white, inner blue. May. 1849.

S. reginae var. *juncea* {syn. *S. parvifolia* var. *juncea*}. About 4ft.h. l.bladeless or nearly so, margin flat. fl. blue and yellow. May. 1796.

S. reginae. Stemless or nearly so; plant about 5 ft.h. l.-blade about 18 in.h. with aq l.-stalk of equal length. Peduncle about as tall as l. fl. large, blue and orange, abundantly produced. April. 1773. A variable plant.

STRELITZIA REGINAE

Reginae, meaning "of the queen," alludes to both the queen Charlotte and the regal plant. The common names for this species are: Bird of Paradise, Bird's Tongue Flower, Crane's Bill, and Crane Flower.

Habit: A shrubby, clumping plant growing 1 to 2 metres (3 to 7 ft) in height with approximately the same spread. Small to large, stiff, somewhat banana-like leaves sprout in dense clusters from mainly underground rhizomes. Individual leaves are 1 to 2 metres (3 to 7 ft.) long, blue-grey in colour; the oblong-ovate blade usually has a reddish mid-rib. Flower bracts are born on sturdy stems 1 to 2 metres (3 to 7 ft.) long; 4 to 6 orange and blue flowers are nestled in grey-green, often purple-tinged beak-like or boat-shaped bracts. Individual new flowers appear as preceding ones age and wither. Double-headed bracts on one flower stem are not uncommon. This plant is ornithophilous, requiring nectar-eating birds to pollinate its flowers; it is also protandrous (each flower's male and female organs are not concurrently receptive to each other), therefore the pollinating birds are required to transport pollen from one flower to another.

Flowers: Each flower consists of 3 outer orange sepals and 3 inner blue petals. The central blue petal appears as a short scale, the two lateral petals from around the five fertile stamens and the style look like a single blue dart. Nectar is produced copiously by a gland beneath the small central blue petal at the base of the flower. As honey-eating birds settle to feed, they grip the blue dart against the bract with their feet, the dart's two petals separate to expose the pollen-covered stamens, releasing the sticky pollen onto the birds feet and under body feathers for transport to the protruding stigma of the next flower. Fruits develop in the bract and reach the size of a small hen's egg; when ripe they split into three sections and reveal up to 80 round, hard, blue-black seeds with bright orange filamentous arils. This seed is also disseminated by birds and ground animals. Hand pollination of *Strelitzia* species is necessary due to the lack of suitable pollinating birds outside its natural habitat of the east coast watercourses of the Cape of Good Hope region of South Africa. In Australia some of our native nectar-feeding honey-eaters will accidently pollinate these plants but this is very unreliable.

Having three large clumps of *S. reginae* with plenty of flowers in my garden, I went about pollinating them, copying the birds, transfering pollen from the stamens of one flower to the stigma of another. The flowers withered and died but failed to set any fruits. The process was repeated a number of times and each time was a complete failure.

Some months later while landscaping an old garden in Kenmore, Brisbane, there were two existing clumps of *S. reginae*

with a good seed set on the old flower heads. The owner informed me that they set seed every year. He also noticed that the mickey bird (*Manorina melanocephala*), or one of the larger and more boisterous native honey-eaters, played in them regularly. I obtained pollen from the flowers of these plants, then cross-pollinated the flowers on my own plants. At last, results—fruit capsules started to form in the bracts at the base of the spent flower. Some eight months later a good crop of seed was obtained.

It seems the secret of success was cross pollination of one clone to another. All the plants in my garden were from the division of one plant, and this was most probably the reason for the early failures. In nature, the clumps consist of seedlings and this accounts for pollination within the flowers of one clump.

Over the years I have tested self-pollination and cross-pollination on the same clump and all results are similar. I have come to the conclusion that cross pollination is necessary for good seed set with all species of *Strelitzia*.

PRESENT METHODS USED TO POLLINATE *S. REGINAE*

(1) **Collection of Pollen.** Pollen is collected from selected plants in a number of locations around Brisbane. This ensures a good range of pollen for cross pollination.

The wings of the blue dart of the flower is pressed open with two fingers to expose the stamens. A plastic drinking straw is used to remove the pollen by sliding the open end of the straw from the base to the tip of the dart. The pollen is then collected up the centre of the straw. This is repeated on other flowers until enough pollen is collected. The pollen laden straws are marked to record the pollen source, and stored in a refrigerator for future use.

(2) **Pollination.** As soon as a fresh flower opens from the boat-like bract, and the white stigma at the tip of the blue dart-shaped petals becomes very sticky, coat the sticky stigma with pollen from the drinking straw. I usually pollinate the flowers in the early morning although reasonable results can be obtained anytime during the day. The main flowering period for *S. reginae* in Brisbane is usually March to July. I usually restrict pollination to that period.

(3) **The seed.** Seed capsules will start to appear in the bracts as a swelling at the base of the spent flower in three to four weeks. In 8 to 9 months (October to February) the capsule will be about the size of a small hen's egg and protrude above the bract. When ripe the capsule splits open in three sections to reveal the blue black seeds. Only remove the split open capsule with a twisting action from the bract, allow to dry and split open completely to remove the seeds. Each capsule will hold 50 to 80 seeds. Most bracts will produce 4 to 6 seed capsules.

PROPAGATION

Seeds are set in 10 cm deep flats in a mix of ⅓ peat, ⅓ perlite and ⅓ fine pine bark. The seeds are covered to a depth of the seed. The flats are placed under 50% shade and germination usually takes place in 6 to 10 weeks during the summer to autumn period. Bottom heat of 35 to 38°C will speed up germination, but in the Brisbane climate it is an unnecessary luxury. Germination from fresh seed is always excellent. Seedlings are then pricked out and potted to 7.5 cm tubes for sale.

Strelitzia is an interesting genus where all species can be hand pollinated as above; a ladder is a great help to pollinate the taller species. Cross pollination between species is also possible and a number of hybrids are available. Strelitzia flowers are the only ones in the world that are known to use a bird's feet as a means of pollination.

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PRODUCTION OF FARM TREES

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There has been growing concern in Australia about the problem of tree decline in the rural landscape. In particular there is a vital need to re-establish tree plantations on farms.

We decided in 1979 that there was an opportunity to participate in and promote an activity which we believed was in the national interest as well as offering a commercial opportunity. One of the reasons farmers do not plant as many trees as they should for their own economic good is that the whole business of choosing species from lists, planning layouts, and getting the planting done, is unfamiliar to them and requires considerable effort.

We recognised that the farmer needed a product package which simplified their task and allowed them to use their own equipment and labour to keep costs down. Hardy species were needed, grown and hardened off to survive freighting and establishment, often in harsh conditions. From the nursery point of view, flexibility in production was essential to provide for the high variability in weather patterns which would strongly influence seasonal buying. A system was developed to meet these requirements, partly by intention and good management, and partly by good fortune.

The following is a brief description of our information and ordering system. It seemed essential to protect the farmer from the complexities of plant names and the choice of species to suit conditions. Since height is the key factor in most cases when planting for windbreaks, the starting point was a colour code for mature heights of the plants. The following system was adopted:

Tall trees	over 12m	blue tubes
Medium trees	6 to 12m	green tubes
Small trees	3 to 6m	yellow tubes
Large shrubs	2 to 3m	orange tubes

Some simple rules have been developed for the design of windbreak plantations. One is that a good windbreak needs a mixture of species to provide velocity reduction at different heights. The farmer can order by colour code, and when his trees arrive, can plant by colour code. These days many of our sales are direct as well as by mail, and the look of relief on a farmer's face when he

finds he does not even have to know the name, *Eucalyptus camaldulensis*, let alone pronounce it, is something to be seen. We provide a plant list with the order form, but in the great majority of cases the choice of species is left to us, based on a questionnaire on soil, climate, drainage, etc., filled in by the farmer.

The coding and nursery selection procedure achieves an important step toward the end result as it allows the best selection of species for the purpose. The next step is to get the trees planted properly and in an efficient layout. Using the colour code, we provide a range of layouts for windbreaks of different heights, numbers of rows, etc. Laying the plants out in the field is then simple, requiring no squinting at Latin names on labels.

Our guide to planting procedure emphasises the importance of tender, loving care, and a surprisingly high percentage of clients take it to heart. The feedback on the whole package has been good, both as to the simplicity of the exercise and the results obtained, particularly compared with previous experience. Above all, we find many people quickly become interested in the whole business and continue planting with enthusiasm.

Two other decisions which we made for good reasons have been fully vindicated, and have brought unexpected bonuses.

First, the container chosen was a square tube 50 mm × 50 mm × 125 mm (2 × 2 × 5 in.), which Hans Kosmer designed for use by the Forests Commission in Victoria. It has many advantages, as its capacity of 250 ml is nearly twice that of the traditional veneer tube, its square shape uses space both in the nursery and in a carton more effectively than round tubes, and above all, the bottom is open which is very important. We were also lucky to find that these tubes were produced for the Commission in a range of colours, so our colour coding problem was solved.

The next decision we made was to use capillary watering. Following Murray Richard's paper (2) at the Perth IPPS conference in 1978 on this technique, we set up a small trial using a synthetic felt—a melded fabric imported from ICI Limited, U.K. It was used for about a year to water ferns in propagating tubes. It was the only water the plants received and was successful. This encouraged us to adopt capillary watering, based on felt matting, for farm tree production. The main reason initially was convenience, but we have since found other very important benefits.

Four tables, each 2.4 m × 1.2 m, are arranged end to end with troughs between each and at the ends of the row (Figure 1). The central trough is a wallpaper pasting trough and it is fitted at one end with a mains pressure water supply controlled by a small float valve and at the other with a 12 mm polypipe connection to the other troughs to control them to the master level. The tables are 500 mm high and the surface is fibre reinforced cement sheet.

Two layers of capillary matting are used. Both the bottom layer,

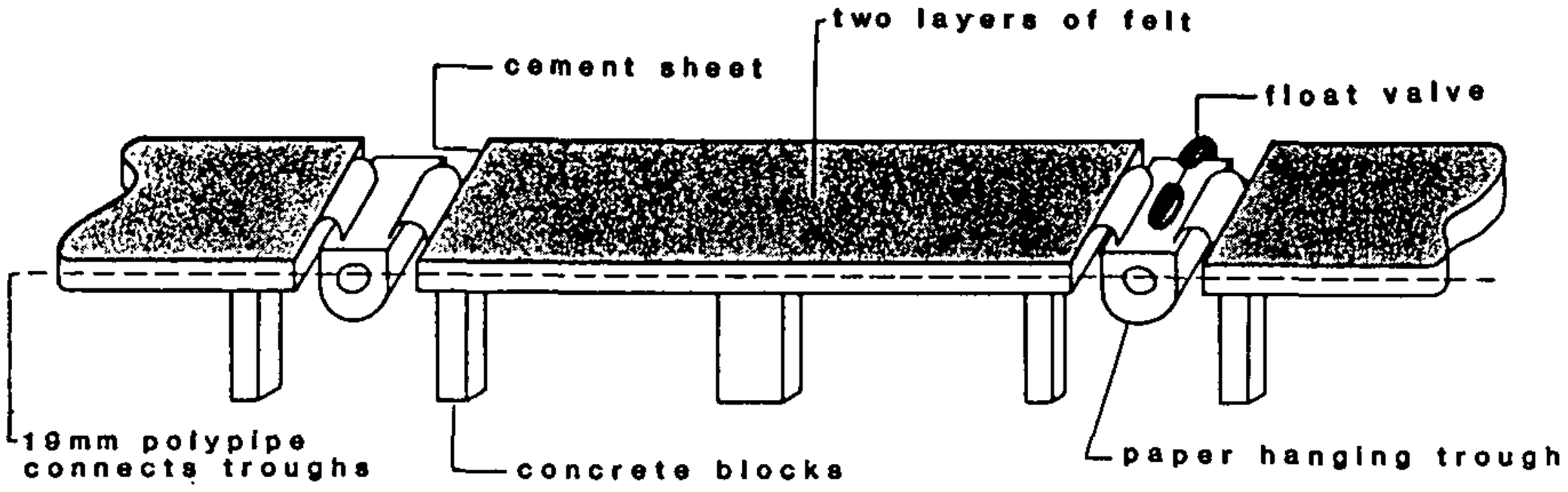

Figure 1: General view of capillary watering system

and the "wick" into the trough, are a white polyester interlining felt, 200g/sq m, used in the clothing trade. This was chosen because its close texture gives it excellent capillary properties, first to lift water about 5 to 15 mm out of the trough, and then to transport it horizontally along the table. The tables are set up with a dip in the middle of about 5 mm which assists the capillary flow.

The black upper felt is a melded fabric—a felt in which the fibres are bonded together in a very open structure. This is manufactured for use as a car carpet by Melded Fabrics Pty Ltd, Dandenong, Victoria. Its density is 350g/sq m. It has inferior capillary properties to the dense bottom felt, but its purpose is to provide a cushion so that the pots, sitting in wire baskets, make intimate contact with the mat. It is also tough and durable.

The tubes are handled in baskets 300 × 200 × 125 mm made from 1.3 mm welded wire fabric, 12 mm mesh, double galvanised. They hold 24 plants. The wire is thin and flexible enough to allow good contact between tubes and matting.

Capillary action in the soil then acts to convey water to the top of the 125 mm (5 in.) deep tubes. Surprisingly little contact with the pot is necessary for effective capillary flow, and the tubes can lie at an angle with only point contact and still provide effective irrigation.

It has been found that capillary watering alone is sufficient to prevent wilting and maintain moist soil up to a few mm from the surface in all but the most extreme conditions. Occasionally, in very hot, windy conditions supplementary overhead watering is applied as a precaution, but it is not often necessary.

One potential problem is the build-up of electrolyte from slow release fertilisers added when potting and when liquid fertilisers are applied overhead. To prevent this, one overhead watering per week is applied if rain has not fallen.

I have said nothing about difficulties, as there are no serious ones that we are aware of. Outbreaks of fungal attack, such as powdery mildew, do not appear to spread any further or faster than we might expect with overhead watering, and they are controlled by

spraying. There is some growth of moss and weeds on uncovered areas of the matting but these are readily cleaned off by scraping with a tile layer's trowel. The build-up of roots from the plants in the mats has little or no effect on their efficiency and, so far, it seems that at least three years can be expected from each felt.

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THE BASICS OF PROPAGATING BOUGAINVILLEA

RUTH E. AULD

Castle Hill Nursery
Castle Hill, New South Wales

Bougainvillea plants grow readily in tropical and sub-tropical areas, and can easily be produced in the Sydney metropolitan area. Care must be taken however, in positioning these plants in the colder and more frosty areas. With careful positioning these delightful scramblers can be encouraged to grow indoors, and in glasshouses and arbortariums.

There is a lucrative market for bougainvillea in Australia, as they give a beautiful display of colour throughout the summer, which makes them very popular.

To successfully grow this plant a sanitation program to eliminate disease should be used. This should begin before the cuttings are taken from the mother plant, rather than trying to arrest problems after the cuttings have been made.

Mother plants are grown in large shrub tubs in polythene tunnels to produce the correct type of cutting material. They are watered by trickle irrigation, because the sprawling habit and the large thorns make conventional watering very difficult.

Mother plants are sprayed on a weekly basis with Zineb at 60 g/100 liters, Benlate 7 g/100 liters and 5 ml wetting agent per 100 liters.

Spraying is discontinued one week prior to cuttings being taken to reduce the hazard to the staff. Cuttings are not sprayed after they are made because the leaves are prone to drop off.

Bougainvillea drop their leaves quickly after being severed from the mother plant if they are not watered immediately. It is

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Bougainvillea drop their leaves quickly after being severed from the mother plant if they are not watered immediately. It is

essential to spray the freshly cut material and the newly-made cuttings.

The ideal time for making cuttings is from early spring to mid-summer (September to January). The wood is considered suitable as soon as the new green growth is firm, and has reached a stage where it will not snap. Cutting material is collected in the early morning and kept moist under mist until all cuttings are processed.

Cuttings are made with double nodes, as these have proved superior to single node cuttings. Cuttings of 15 to 17 cm in length are severed 0.5 cm below the bottom node. The lower leaves are removed and the top leaves are halved. Cuttings can also be made by removing all leaves. This has proved successful, as sometimes they will drop all halved leaves anyway before striking.

The bottom 7 mm of the cuttings are treated with a 5 sec. quick dip of 4% IBA and are planted in community 17 mm squat pots, with 25 cuttings to a pot. Each pot has 15 mm of 5 mm sterile pea gravel placed in the bottom with the remainder of the pot filled with coarse washed river sand.

The pots are placed in the glasshouse under intermittant mist, using a thermister set at 60% humidity. No bottom heat is used as cuttings strike well without it during the summer months.

Callus forms in 3 to 4 weeks and roots are initiated from 6 weeks onwards. No dead leaves or material is removed from the pots during this period, and this has not caused a problem.

After 7 weeks the cuttings in pots are removed from the glasshouse and placed in the shade house to harden off for about 10 days. They are syringed with water during the hottest part of the day.

The strike rate is usually 85 to 90%, but some cuttings which have not struck are re-cut back to the second node, re-dipped with IBA, and placed back in the glasshouse and struck at a later date. This proves the value of double node cuttings.

Great care must be taken when removing bougainvillea cuttings from the pots to be tubed. This is a very crucial part of their production as their roots are very brittle and are prone to breaking when disturbed.

The method we use is called "floating out" and has proved very successful. A large wheelbarrow is half filled with clean water and the pot of cuttings is submerged. The pot is gently tilted, and the roots are gently floated away from the medium. It is important not to pull or shake the roots. This method may take a little more time than the conventional knocking-out process, but is well worth the extra time and effort.

Cuttings are then potted into 75 mm grow tubes with John Innes soil mix and placed in poly tunnels until they are large enough to be transplanted into 150 mm pots. Once in the 150 mm pots they are staked and returned to the poly tunnels.

In late winter plants are treated with 5 grams of potassium nitrate to each 2.5 litre pot to induce flowering. There is a product called "More Bloom" which can also be used to induce flowering.

When all danger of frost is gone, and the flower buds are beginning to develop, the plants are moved out into full sun. They are also top-dressed with sand together with hoof and horn meal; this promotes rapid growth enabling the plant to reach a salable size.

The potting mix used was as follows:-

46 cubic metres sawdust
11.5 cubic metres pinebark
11.5 cubic metres "coke breeze"

The "coke breeze" improved drainage and aeration. The following fertilizers were added to compost the sawdust mix:-

single superphosphate	28kg
gypsum	60kg
iron sulphate	12kg
Agra-mag 95%	30kg
potassium sulphate	46kg
Esminel	12kg
urea (46N)	140kg

A dressing of three-year-old chicken manure is added to the mother plants after cuttings are taken. These plants produce strong vigorous growth for future cutting material following this dressing.

Care must be taken not to over-fertilise bouganvillea as they produce unwanted water shoots and lush growth which inhibits flowering. Plants which flower successfully are grown under harder conditions.

Castle Hill Nursery produces 50,000 bougainvillea plants of the Rhodesian and Hawaiian cultivars each year. These can all be grown in the Sydney metropolitan area.

Bougainvillea can be successfully propagated provided all the procedures mentioned above are followed. In particular, the taking of cuttings, the timing, and the handling of rooted cuttings, are the most important operations.

COPING WITH ADELAIDE'S WATER SUPPLY USED FOR PROPAGATION

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This is not a scientific presentation but a factual record of the strife a plant propagator can get into if the quality of the water one is using is taken for granted.

When we began our nursery, life was fairly straightforward. Seeds were sown, cuttings were planted, and we enjoyed reasonable success with the majority of lines attempted.

In the summer of 1980/81, however, our results began to deteriorate and in the next two years it seemed that we may have to give up propagation. We could not get roots on *Lamium* or *Maranta*. *Asparagus densiflorus* 'Sprengeri' seeds were reluctant to germinate, though *Dracaena draco* was still cooperative. All the trays on the heated benches were looking dreadful.

The chemical analysis of the propagating mix began to tell a story, though their correct interpretation took some time.

The test results were:

	pH	*Salinity (E.C. × 103)*
Propagation mix before use:	4.9	2.55
Propagation mix taken from trays after 4–5 weeks	4.3	6.7
Optimum values:	6.0	less than 3.0

The mix used was basically the one recommended by Cornell University as described in Hartmann and Kester (1), but it was obviously too acidic. The salinity levels after 4 to 5 weeks were well outside acceptable limits.

Very few salts were added to the propagation mix, and the question arose as to the origin of the saline condition of the mix. The answer was obvious of course—the salinity was being increased by the continual watering, and the high evaporation of water from the heated benches.

This situation had existed for years though, without experiencing these troubles, so what was new? The answer turned out to be double-barrelled.

In the past the mains water in Adelaide had always been hard, but this hardness was brought about by high amounts of magnesium and calcium carbonates. Most kinds of plants were fairly tolerant of these materials and even put up with the added fluoride, as well as the large amounts of chlorine introduced from time to time.

But now we were experiencing a drought, and a large propor-

tion of the city's water was being pumped from the Murray River, and with this water came loads of sodium chloride.

At about the same time the Engineering and Water Supply Department began filtering the water being supplied to our area. This involved floculating the suspended clay from the Murray River water. Alum was added to cause the clay particles to congregate and be filtered out. Lime was then added to restore the pH to more or less neutral.

One solution to our problem was to switch to rain water collected from the sheds and glasshouses. Another catch—what happens when it does not rain? There was really only one answer—to buy a de-salinator.

We did this, and with a pressure attached pump, we now have de-salinated water distributed to the propagating areas. The salinity of the water was reduced from 700 ppm (which included 250 ppm sodium chloride) to about 200 ppm, with an almost total elimination of sodium chloride.

The de-salinated water costs about five times that of normal mains water, but we can now germinate most seeds easily, put roots on *Lamium* with the old weed-like ease, and we even have success with some of the more difficult lines.

It may be asked why other nurseries did not have similar difficulties? Some did, but others were not as dependent on heated

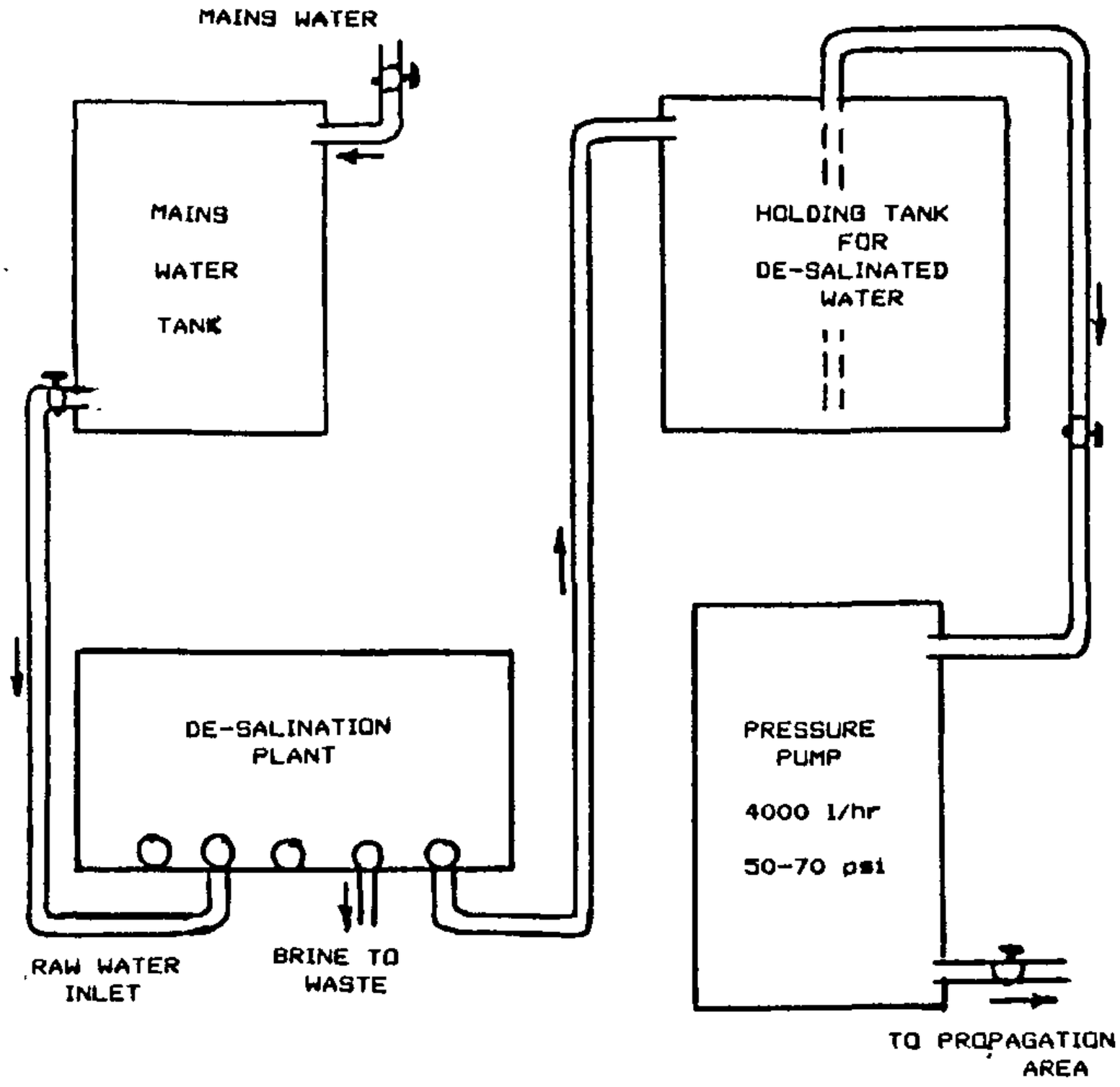

Figure 1. Schematic representation of de-salination system.

benches as we were. Others, like bedding plant growers, and some who were propagating with fast-germinating native seeds, were able to avoid the accumulation of salts in their propagation trays.

We still water our tubed plants with normal mains water—the *problem was in the propagation area.*

Figure 1 gives details of the de-salination plant.

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HYGIENE AND THE USE OF TISSUE CULTURES IN THE NURSERY INDUSTRY

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I would briefly like to examine the importance of hygiene in the preparation of stock plants for tissue culture and in the planting out of tissue cultures. These are the two areas where the nursery propagator and the tissue culture laboratory interact, and for the relationship to be effective and trouble free there must be communication and understanding between the two spheres of activity. I think these two areas are worth exploring at an I.P.P.S. meeting.

Research is expanding the range of products which can be produced by commercial laboratories and tissue culture is going to become a more routine feature of propagation. Therefore theorists and practioners from both areas urgently need to come to grips with each other's requirements.

A combination of higher capital costs, higher labour costs, rising taxes and on-costs must cause the nurseryman to examine his/her nursery turnover in terms of dollars per square metre of floor space. The true cost of producing cuttings should include a calculation of the worth of the floor space occupied by the stock plants in terms of what that space could generate if turned over to straight production. In the not too distant future floorspace may become so valuable that the only stock plants you can afford to hold are those expensive lines which cannot be satisfactorily produced by tissue culture.

Obviously there are a number of equally important aspects of stock plant preparation and planting out which could be examined

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I would briefly like to examine the importance of hygiene in the preparation of stock plants for tissue culture and in the planting out of tissue cultures. These are the two areas where the nursery propagator and the tissue culture laboratory interact, and for the relationship to be effective and trouble free there must be communication and understanding between the two spheres of activity. I think these two areas are worth exploring at an I.P.P.S. meeting.

Research is expanding the range of products which can be produced by commercial laboratories and tissue culture is going to become a more routine feature of propagation. Therefore theorists and practioners from both areas urgently need to come to grips with each other's requirements.

A combination of higher capital costs, higher labour costs, rising taxes and on-costs must cause the nurseryman to examine his/her nursery turnover in terms of dollars per square metre of floor space. The true cost of producing cuttings should include a calculation of the worth of the floor space occupied by the stock plants in terms of what that space could generate if turned over to straight production. In the not too distant future floorspace may become so valuable that the only stock plants you can afford to hold are those expensive lines which cannot be satisfactorily produced by tissue culture.

Obviously there are a number of equally important aspects of stock plant preparation and planting out which could be examined

(e.g. nutrition, seasonality, environmental control, water quality, root formation), but I have chosen hygiene because it is often neglected and can be the cause of severe problems between nurseries and laboratories. This paper concentrates more on what the grower can do to optimize the process than on what the laboratory can do.

Much of the information presented here is a result of experience and observation. I have no doubt that many of these things have been said before, but I think there is no better time than now to bring these issues into sharper focus.

PREPARATION OF STOCK PLANTS

There are two common scenarios encountered when initiating plants into culture:

(a) The laboratory has extreme difficulty in getting the material into culture due to recurring heavy infections. This can cause the lab to go through large amounts of stock material before achieving success, or to not achieve success at all.

(b) The plant is put into culture with some low level infection which causes progressively greater problems as production builds.

The overall result is often very long lead times, unreliable production, and difficulty in planting out at the nursery. Although the initiation of material into culture is largely dependent on the skill of the laboratory, there is a good deal that the grower can do to minimize infection problems and so give the laboratory the best possible chance of getting the material cleanly into culture.

Initiation of plant tissue cultures can be achieved from a number of parts of the plant—shoot tips, lateral buds, stem tissue, leaf tissue, petioles, floral buds, roots, rhizomes, etc. The organ chosen depends on the plant in question. In order to grow any of these in culture the surface contamination must be removed, and this is done by treating the piece of tissue with a sterilant such as sodium hypochlorite. A balance must be struck between treating the material harshly enough to remove all surface contamination and not so harshly that the plant tissue is killed or suffers debilitating damage. The disinfestation process is a numbers game—strength of sterilant vs. number of microbes on the surface of the piece of tissue. The propagator can greatly assist this process by hygienic preparation of the stock plants, and taking the following precautions:

(a) *Stock quality*—Use only vigorous, mature plants with no symptoms or history of disease. Mature plants have not only had time to show their best characteristics, they have also had time to show up any slowly developing diseases they might be harbouring.

(b) *Potting mix*—A clean, preferably pasteurized potting mix helps to keep down the level of contamination immediately around

the plant. This is particularly important where underground parts of the plant must be used. Experiment with potting mixes to get the best combination of growth and cleanliness. Rich, untreated, organic mixes should be avoided at this stage if possible, because they are usually heavily contaminated with soil bacteria.

(c) *Pots and tools*—These must be totally clean at all times. Used pots should be scrubbed out with bleach or some other disinfectant and tools dipped in bleach before being used for mother plants.

(d) *Environment*—In a final preparation phase a few weeks before culture initiation, plants should be shifted out of the greenhouse where humidity and contamination is high and placed in a clean, dry, well-ventilated environment. In conjunction with clean potting mix, this can substantially lower the surface contamination of the plant.

(e) *Water*—In the final preparation phase the plants should be hand watered to avoid wetting the foliage and splashing soil onto the plant.

(f) *Field specimens*—For initiation of cultures from field specimens such as trees, plastic sheeting can be used as splash barriers to prevent rain from splashing soil on the foliage to be used, and pests and diseases should be treated around the immediate area.

In general, a soil-spattered plant presented in a damp earthenware pot filled with compost and blood and bone and carrying a few crawling insects and a spot of two of fungus won't be received with enthusiasm by a laboratory. However, a clean, pest-free plant presented in a clean, dry, plastic pot filled with pasteurized soil mix containing few organics will be met with great appreciation.

PLANTING OUT

The successful planting out of tissue cultures involves cooperation between the laboratory and the nursery, and each has their areas of responsibility with respect to hygiene.

The laboratory has the responsibility to deliver healthy cultures displaying good colour, good vigour, no blemishes—and they must be pathogen-free. If they arrive in this state, then it is reasonable to assume that you will have a trouble-free plant-out, all other factors being equal. Occasionally there are low levels of visible infections in tissue cultures, and these cultures should be planted-out in consultation with the laboratory. If cultures are very visibly contaminated, then the laboratory should give prior warning and advice on handling. These infections are seldom plant pathogens, but by their very presence in the cultures they are competing with the plant for nutrients. It is reasonable to assume that they could possibly interfere with the planting-out process. Our present knowl-

edge of these microbes is so poor that we cannot become dogmatic about whether or not they cause harm. Clearly, some nurseries have consistent success with cultures, both clean and infected, while other nurseries produce poor results with the best quality cultures.

The responsibility of the nursery is to plant out the cultures under the best possible conditions. The following points should be noted:

(a) *Use a pasteurized potting mix*—Tissue cultures come from an aseptic environment. We know very little about the microbes which normally live in association with plants in open cultivation, and in tissue-culturing the plant we may have removed not only antagonistic organisms but also any which may have afforded protection or conferred an advantage to the plant when encountering pathogens. A clean soil mix with a low population of microbes must ease the transition for the plant back into open cultivation.

(b) *Use sterilized tools*—Always be scrupulously clean with implements when planting out. Tools should be washed in sodium hypochlorite or equivalent to ensure that pathogens are not transmitted.

(c) *Salinity and pH*—High salinity and pH can cause severe damage to tissue cultures and can bring about heavy losses from damping-off at any time.

(d) *Fungicide*—Spraying with a fungicide is a matter of judgement for a given nursery working with a given product, but preventative spraying is usually a good idea.

(e) *Time*—Tissue cultures should be inspected immediately upon delivery and planted out within a few days. The cultures should have been delivered in their optimum growth phase, and substantial delay in planting out will only cause them to deteriorate, both for physiological and hygienic reasons. Delivery containers for tissue cultures are not air-tight, and air has moved in and out of the containers with changes in temperature and air pressure, especially if the cultures were air-freighted. Thus when they reach the nursery, they have probably taken in some fungal and bacterial spores from the air. These may develop if the cultures are left to sit for any length of time at the nursery. Also, cultures left sitting on a floor or bench for a week or more invariably attract very small mites which enter the jars and spread spores among the plants. This may not become apparent until the cultures have been planted out and suddenly exhibit signs of the infection.

CONCLUSIONS

This paper represents a practical attempt to help the nurseryman overcome some of the hygiene problems associated with the development and use of tissue cultures. I would encourage all

nurseries using or contemplating the use of tissue cultures to experiment extensively with their propagating facilities to optimize their success. Those nurseries which have established good success rates with cultures should be analysing very carefully the factors responsible for that success, just as those who have not had success need to experiment to find out the source of their problems. I believe that in a short time tissue culture will become a conventional technique in the nursery industry in Australia and we must begin now to take the guesswork out of preparation of stock plants and planting out of tissue cultures.

SELECTION AND GRAFTING STUDIES OF *BANKSIA COCCINEA* AND *BANKSIA MENZIESII*

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INTRODUCTION

Banksia species are showing great promise as a plantation-grown cut flower crop in South Australia where currently 56 ha are under cultivation. Two species with outstanding flowers and high export potential are *Banksia coccinea* (the scarlet banksia) and *Banksia menziesii* (raspberry frost banksia). *Banksia coccinea* has a reputation of being difficult to grow and is currently grown commercially only in well-drained acid sands in South Australia and Victoria. The flower is recognized in overseas markets from the export of bush-harvested blooms from Western Australia. There has been little success in cultivation overseas.

In addition to the striking appearance of the bloom, *B. coccinea* is suitable for export due to its small to medium size, relatively fine straight stems, compact leaves, and terminal flowering habit without side breaks. Considerable variation exists in populations in relation to flowering period (May to December) and color of blooms (yellow, orange to deep scarlet). A selection program for this species should concentrate on the following criteria:

1) Selections to extend the bloom season to provide for continuity of supply in export markets.
2) Identification of colour variants.
3) Identification of an outstanding high yielding true red cul-

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1) Selections to extend the bloom season to provide for continuity of supply in export markets.
2) Identification of colour variants.
3) Identification of an outstanding high yielding true red cul-

tivar with lightweight stems to lead as the species standard.

4) Disease resistance and tolerance of heavier soils.

Banksia menziesii is one of the slower-growing commercial species which deserves attention due to its highly desirable terminal flower. Again, seedlings can exhibit a range of growth habits which can greatly influence yields of marketable flowers.

Both a tree form (to 10 m) and a lignotuber-forming shrub (to 3 m) exist in natural populations, the shrub being most commonly grown in commercial plantings. Considerable colour and size variation occurs in blooms and there is often a tendency towards short stems. Again, this species would benefit from selection and clonal propagation for cut-flower production.

There has been considerable interest shown in grafting Western Australian banksias on to eastern species which are more tolerant of disease and poor soil conditions. Work in Western Australia (4) has defined *Banksia* species which have potential for use as rootstocks due to resistance to *Phytophthora cinnamomi*, the most important disease of banksias under cultivation. Of the species studied, *Banksia integrifolia* appears to have the greatest potential as a rootstock. It is a species tolerant of high phosphorus levels and poorly drained sites, shows high level of resistance to *Phytophthora*, and is easily propagated from cuttings. The S.A. native *Banksia marginata* deserves assessment as a rootstock for local plantations. This species occurs over a wide range of soil types and shows moderate resistance to *Phytophthora*.

Reported grafting work on banksia species has not clearly determined compatibility of desirable cut flower species with selected rootstocks. McCredie et al. (3) utilized a hot-callusing tube to facilitate graft unions of 8 scion species on 5 rootstocks. Greatest success was achieved with *Banksia hookeriana* (1 take on 18 attempts) on *B. integrifolia* rootstock. Final assessment at 4 months was inconclusive concerning long-term compatibility. McKenzie (5) in Victoria has reported grafting studies with a wide range of banksia species. Compatibility is assessed for most species but there are no notations of successful field establishment.

Grafting is widely practiced on macadamia, another member of the Proteaceae. It is standard nursery practice to girdle branches used for scionwood six weeks prior to collection (2). Girdling allows for carbohydrate accumulation in the stems which appears necessary for grafting success in this species. This technique deserves assessment on all proteaceous species suitable for grafting.

MATERIALS AND METHODS

Seedling rootstocks of *Banksia integrifolia* and *B. marginata* were grown in 2 litre bags to a stem diameter of pencil thickness at

approx. 12 to 15 cm height. Rootstocks were moved into a glasshouse 1 week prior to grafting and maintained at a temperature of 15 to 30°C during a 8 to 10 week period after grafting.

Scionwood was collected from mature, flower-producing plants of *Banksia coccinea* and *B. menziesii* grown on plantations in Millicent and Happy Valley, S.A. Four weeks prior to grafting, several branches that would provide scionwood were girdled by removing a 1 cm ring of bark. Scion sticks were prepared approximately 10 cm long with 2 or 3 leaves from hardened current season's wood of pencil thickness.

All grafting in these trials utilized a simple wedge graft, the unions being wrapped with budding tape or Parafilm and waxed. A loose plastic bag was placed over the scion to reduce desiccation.

The first trial commenced in late May 1985 and was evaluated at 8, 12, and 20 weeks. Several successfully grafted plants were then field planted in early spring (September). The second trial commenced in September and involved grafting 200 plants, utilizing the best treatments of the first trial. Faulty temperature controls in the greenhouse over a weekend led to loss of all grafts except the 75 reported in Table 2.

RESULTS AND DISCUSSION

Table 1 summarizes the results of the first grafting trial on 60 plants each of the two rootstock species, *Banksia marginata* and *B. integrifolia*.

Table 1. Grafting trials commenced in May 1985 with four *Banksia* species.

Scion/Rootstock	Number/ treatment	Number plants alive at: 8 wk	12 wk	20 wk	Number plants showing scion development at: 8 wk	12 wk	20 wk
1. *B. coccinea*/ *B. marginata*	15	15	14	10	11	12	8
2. *B. coccinea*/ *B. marginata* (girdled)	15	14	11	6	7	10	4
3. *B. coccinea*/ *B. integrifolia*	15	14	10	4	5	5	4
4. *B. coccinea*/ *B. integrifolia* (girdled)	15	15	14	6	13	14	6
5. *B. menziesii*/ *B. marginata*	15	5	3	3	1	2	2
6. *B. menziesii*/ *B. marginata* (girdled)	15	14	14	13	6	11	8
7. *B. menziesii*/ *B. integrifolia*	15	4	4	3	1	2	3
8. *B. menziesii*/ *B. integrifolia* (girdled)	15	11	10	9	2	5	4

BANKSIA COCCINEA

The first assessment at 8 weeks showed that *B. coccinea* scions had started to develop in 60% of the grafted plants. This figure increased at 12 weeks and declined by 20 weeks when a final assessment of 36% successful takes was recorded. Girdling the scion wood of this species had no affect on success of graft take.

It is encouraging to note the rather rapid movement of *Banksia coccinea* scions after grafting, indicating quick callusing and union with the stock. *Banksia menziesii*, by comparison, showed development of scions in only 16% of the grafted plants at 8 weeks. The dieback of scions during the 12 to 20 week period corresponds with the period of unwrapping of the graft unions and movement of plants from the greenhouse outdoors into a nursery environment in winter. Scion loss can be attributed in some degree to premature unwrapping and possible desiccation of the graft unions which appeared to split or peel back at the narrow edges of the cut on the rootstock. Temperature changes to the grafted plants had the affect of arresting scion devleopment which may have been detrimental to continued graft healing.

In September, 30 additonal grafts made of *B. coccinea/B. integrifolia* with non-girdled scion wood survived and were assessed up to 6 months (Table 2). Results of survival at 6 months (31%) and scion development at 8 weeks (60%) were very similar to the first trial. Scions grew to an average of 15 to 40 cm in height.

Table 2. Results of grafting trial commenced September, 1985

Scion/Rootstock	Number/ treatment	Number plants alive at:		Number plants showing scion development at:	
		8 wks	6mo.	8 wks	6 mo.
B. coccinea/ B. integrifolia	30	30	15	18	11
B. menziesii/ B. marginata (girdled)	15	11	3	7	2
B. menziesii/ B. integrifolia (girdled)	15	5	0	0	0

BANKSIA MENZIESII

Results with *B. menziesii* showed significant differences between girdled and non-girdled scionwood on both species of rootstock. At 8 weeks, 70% of non-girdled grafts had failed, while only 17% of girdled material was lost. Scion development was slow in all treatments and at the end of 20 weeks, 73% of the girdled grafts survived but only 40% showed scion development at this time.

In the second trial (Table 2), only girdled scion wood was utilized and there were no surviving grafts with *B. integrifolia* rootstock. Low survival rates with *B. marginata* may also indicate that seasonal factors need to be thoroughly understood before optimal

conditions for grafting success can be recommended.

The results of these trials indicate that potential exists for grafting the species *B. coccinea* and *B. menziesii* onto rootstocks. It must be noted, however, that there was a trend towards graft failure apparent at 20 weeks. A number of developing scions were observed to wilt, the leaf margins browning and drying. When the graft of these scions was examined it was clear that the union between scion and rootstock was poor. Callus development was minimal in these cases and the graft union broke easily when twisted. This indicates either incompatibility of *B. coccinea* and *B. integrifolia*, or that insufficient time was allowed before the grafts were unwrapped and the scions subjected to environmental stress. Grafting studies with these species and several other banksias will be continued by the Department of Agriculture in 1986–87 at the Loxton Horticultural Research Station.

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ASSESSMENT OF CERTAIN NATIVE AUSTRALIAN SPECIES IN SALT-AFFECTED AREAS AND THEIR PROPAGATION TECHNIQUES

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Commercial tissue culture propagation of salt-tolerant clones of eucalypts has been started by a South Australian nursery company, Land Energy Laboratories, Pty Ltd. Clones of salt tolerant genotypes of *Eucalyptus camaldulensis* and *E. occidentalis* will have an application in salt land reclamation, and in mine dump rehabilitation applications.

The clones could feasibly produce a biomass energy tree crop on large areas of abandoned irrigation farmland affected by increasing salinity and rising water tables. There is a perceived future in using superior clonal eucalypt material to rehabilitate degraded lands not only in Australia but also overseas.

A tissue culture laboratory has been established at Macclesfield to complement the existing tubestock nursery operated there by its affiliate, Land Energy Pty Ltd.

Young seedlings of selected species and provenances are first screened for their ability to survive and grow in increasing concentrations of salt water, as high as 80,000 EC (electrical conductivity) units for about 12 weeks. Those individuals that perform best under salt water screening are then clonally propagated using techniques developed primarily by CSIRO's Division of Forest Research.

Once developed, the tiny plantlets are transferred from the laboratory into tube containers for hardening off and growing on in the nursery environment. From four to six months is required from the start of tissue culturing to the time the material is ready for field planting (Figure 1.)

Several clones of *E. camaldulensis* have been planted over the last year in field trials, along with seedlings of other species and provenances, to determine the most suitable trees for the production of fuelwood on marginal lands. Funded by a State Energy Research grant (SENRAC), Land Energy will establish some 30 different clones and provenances on seven trial sites in various areas in South Australia.

Although there are a number of different genera represented in these trials the main emphasis is on *E. camaldulensis* because of that species' capacity to remove water from the ground into the atmosphere (evapo-transpiration).

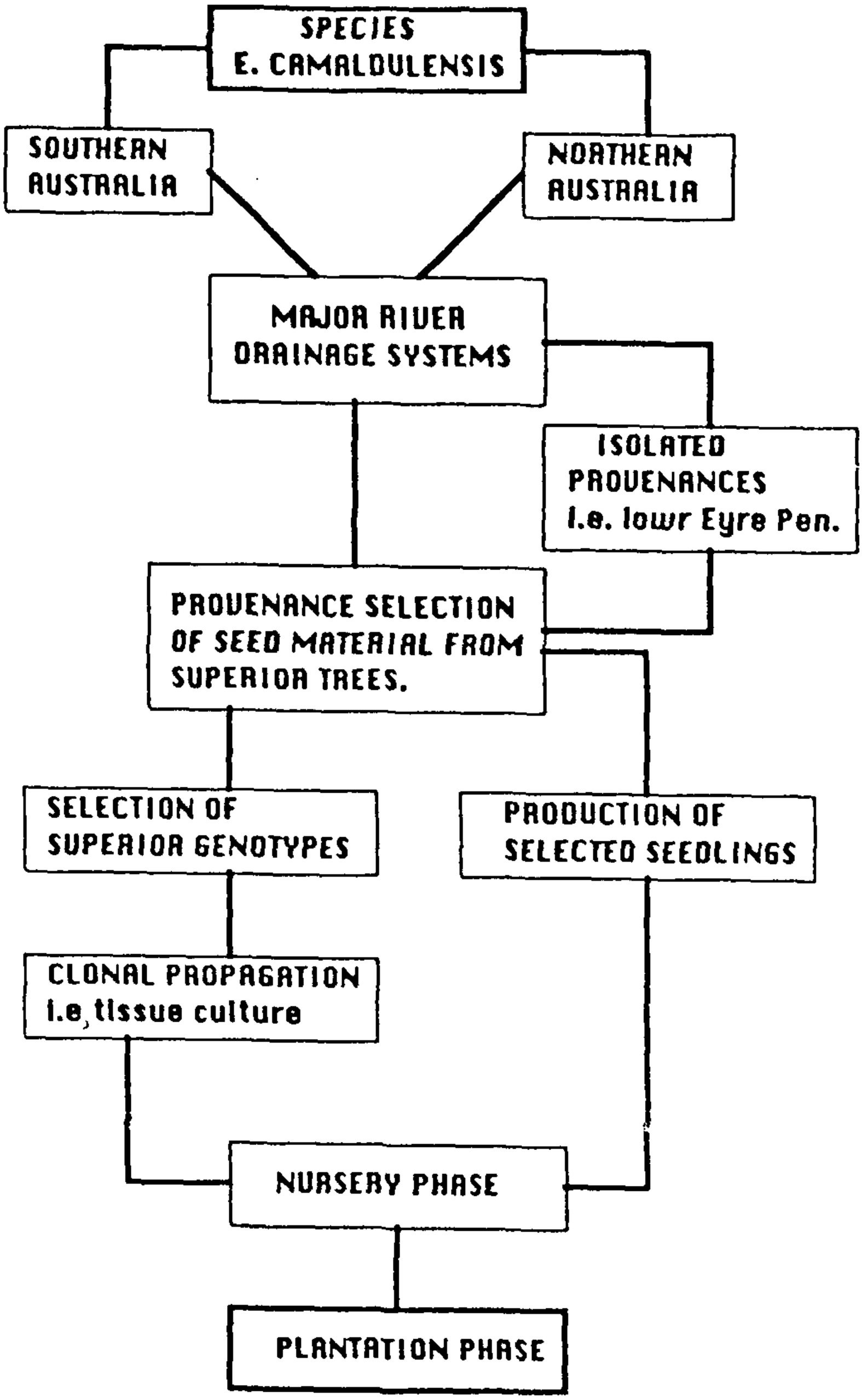

Figure 1. Plant material selection model

VARIATION IN *E. CAMALDULENSIS.*

This species of eucalyptus, of the 511 currently described, is the most widespread geographically. It is always associated with water, either river systems or accessible groundwater, hence it's colloquial name "River Red Gum." Because of its wide range there is significant variation in its growth response in a managed environment.

Variation in red gum is well known. Perhaps the most formative work done in this area was carried out by the Food and Agriculture Organisation of the U.N. in the 1970's under the supervision of a French scientist, J. F. Lacaze.

Lacaze planted trials consisting of 44 collections from 34 provenances in 39 trials in 21 countries in Asia, Africa, and in the Mediteranean Basin. His early assessment indicated that the difference in growth performance between the best and worst was at the ratio of 8:1. Similar trials in Israel (Karschon) and in California and Australia support these findings.

Several of the sites, including a site at Lake Bonney near Barmera are affected by severe soil salinity and high water tables resulting from a range of factors including lateral seepage of irrigation water from adjacent orchards and vineyards.

It is estimated that in the Riverland region alone, there are now thousands of hectares that have been rendered unproductive due primarily to irrigation-induced salinity. Data from each trial site will be processed and the results will provide information on the survival and growth parameters of each species and provenance. Furthermore, the results in time will show the potential for the economic reclamation of these degraded lands through the establishment of a fuelwood growing industry.

The same basic approach can be used for the identification and propagation of a range of salt tolerant ornamental species. The major difference here is that these species can usually be propagated using conventional vegetative methods. (e.g. mist propagation). Eucalypts, on the other hand, do not normally respond to these methods, hence the need for a micropropagation approach.

THE GARDENS OF IRELAND

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Abstract. Ireland lies between 51.5° and 55.5° N latitude. The climate is essentially maritime being influenced by the Gulf Stream and the relatively warm waters of the North Atlantic Drift which reach the coastline of Ireland and northwest Europe.

Ireland's mild, oceanic climate is characterised by equable temperatures, plentiful rainfall in most seasons, overcast skies, and high humidity. Conditions are suitable for the growth of a wide range of temperate trees and shrubs. In addition, many sub-tropical species, such as banana (*Musa basjoo*), tree ferns, *Echium pininana*, *Callistemon* spp. and *Dacrydium* spp., thrive in the open in mild areas. With some notable exceptions most of Ireland's best known gardens occur near to the coast.

Although the climate in Ireland is generally favourable for gardening, wind and year-round weed growth are two potentially major handicaps. Gales and strong winds are common; salt damage occurs frequently in coastal gardens and occasionally some distance inland. A wide range of plants is used to form windbreaks including *Pinus muricata*, *Cupressus macrocarpa*, *Escallonia rubra* var. *macrantha*, and *Olearia macrodonta*.

Herbicides can be used particularly effectively in Ireland to suppress weed growth. The rainfall, fairly evenly distributed throughout the year, enables soil-acting herbicides such as simazine to be used more effectively than in many other countries. In addition, the generally high organic matter content of the soil reduces the risk of plant damage. Herbicides have a major advantage in landscape maintenance in shifting major weed control activity from the busy late spring/early summer period to the late autumn/winter period when labour is more readily available.

INTRODUCTION

The Gulf Stream and the North Atlantic Drift, originating in the Gulf of Mexico, have a major influence on the climate in Ireland and consequently on Irish gardens. This current and the predominantly southwesterly winds that blow over it and are warmed in the process, gives Ireland an essentially maritime climate of mild winters, cool summers, and year-round rainfall.

Ireland lies nearer to the North Pole than to the Equator and is further north than Newfoundland. If it were not for the warm westerly winds, the Atlantic Ocean, and the Gulf Stream, Ireland would be icebound for part of the winter, somewhat similar to the Labrador coast of North America. In contrast the temperature of the coldest month (January) ranges from 7°C in the south to 4°C in the north. Figure 1 shows that the temperatures in southern Ireland during January are similar to those in the Mediterranean areas of Europe. Apart from the Midlands, most of Ireland seldom experiences freezing days when the temperature fails to rise above 0°C (Figure 2). Long spells of low temperatures sufficient to kill less hardy plants are exceptional.

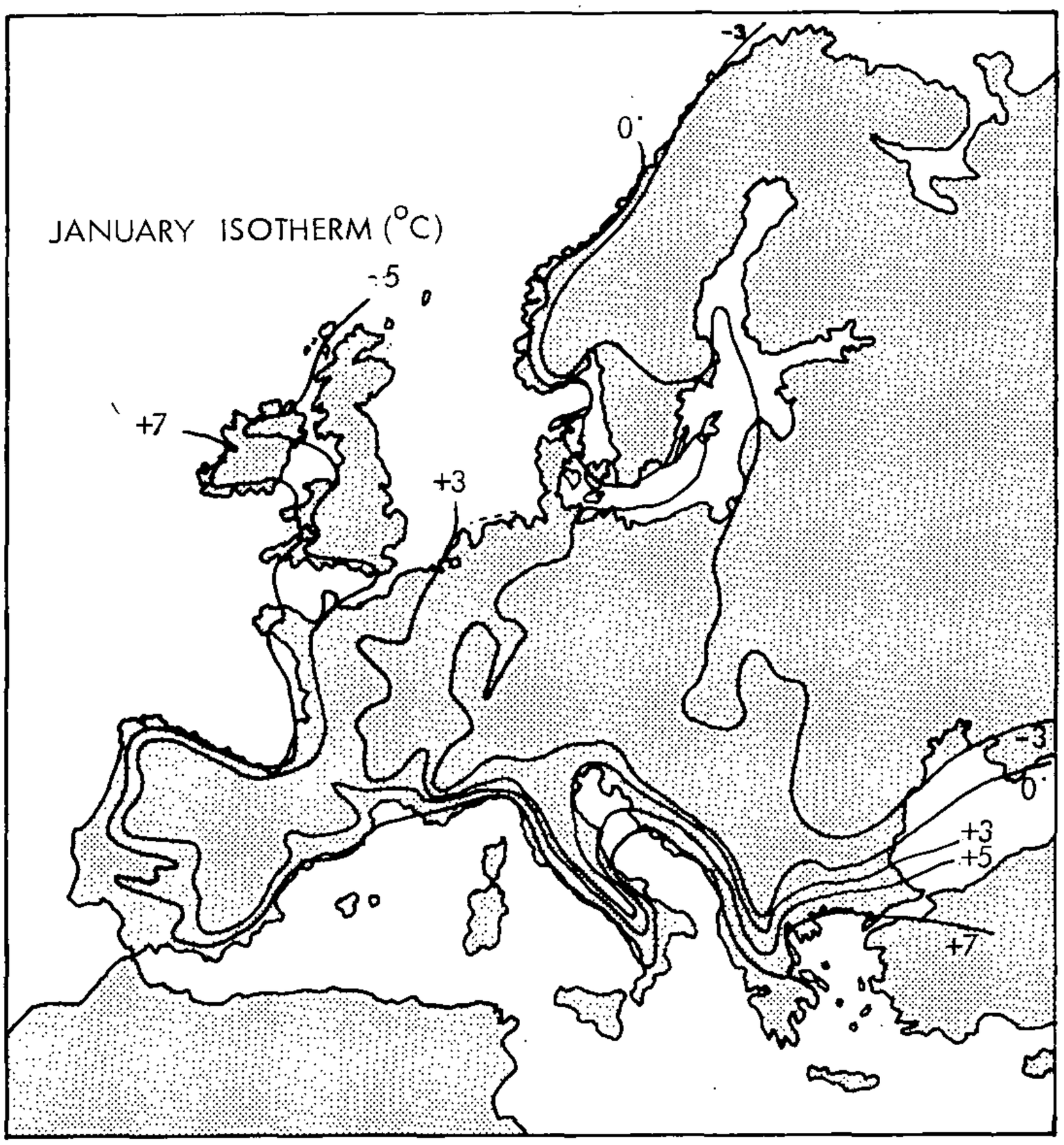

Figure 1. Isotherms (−3, 0, 3, 5, and 7°C) for Europe in January. (Source—World Survey of Climatology, Vol 5; Elsevier Publishing Co.)

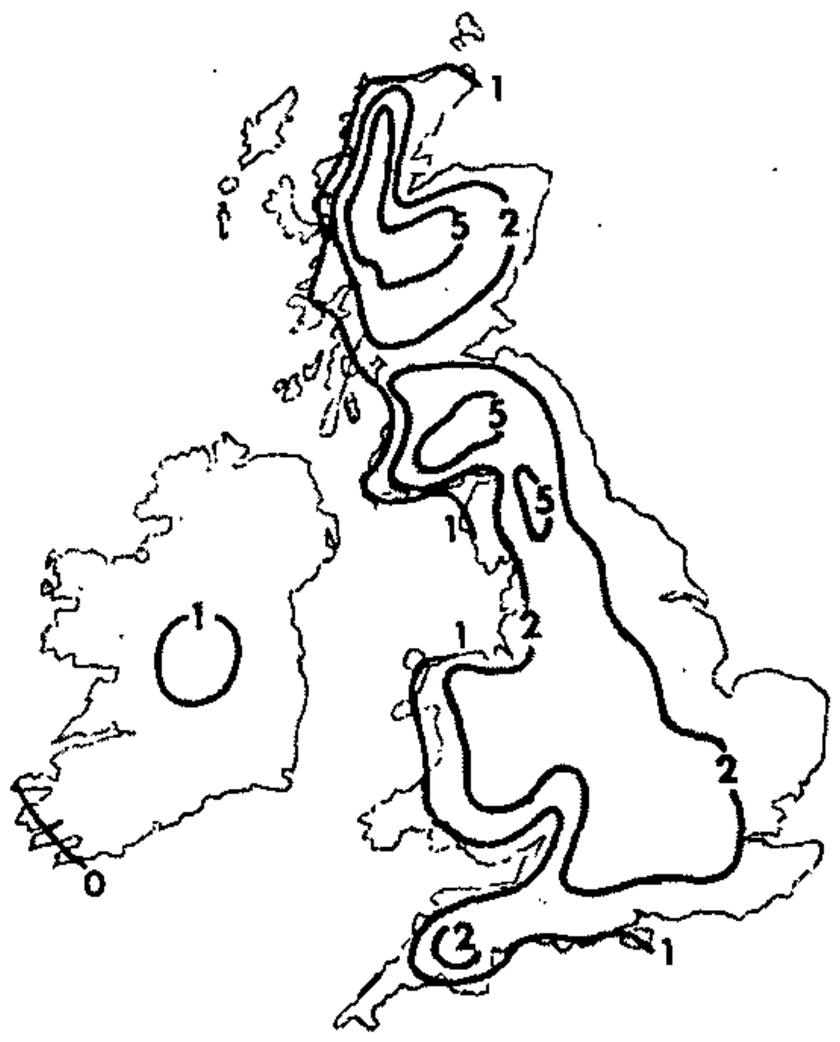

Figure 2. Frequency of freezing days in the British Isles when the temperature failed to rise above 0°C (Source H. H. Lamb, The English Climate)

Summer temperatures are comparatively low. The mean daily temperature for the warmest month (July) is 14.5° to 16°C for most lowland areas (Figure 3). Prolonged summer heat, like extreme winter cold, is uncommon. In the southwest part of Ireland there is only 8°C difference in temperature between the means of the coldest and warmest months and only 10 to 11°C difference in most of the rest of the country.

Rainfall varies from 800 to 1000mm in the drier East and Midlands and from 1000mm to over 2000mm in the South and West. Rain falls every month of the year, although there is a tendency for March to June to be the driest months and December the wettest. Each of the twelve months has been the wettest or the driest in some year.

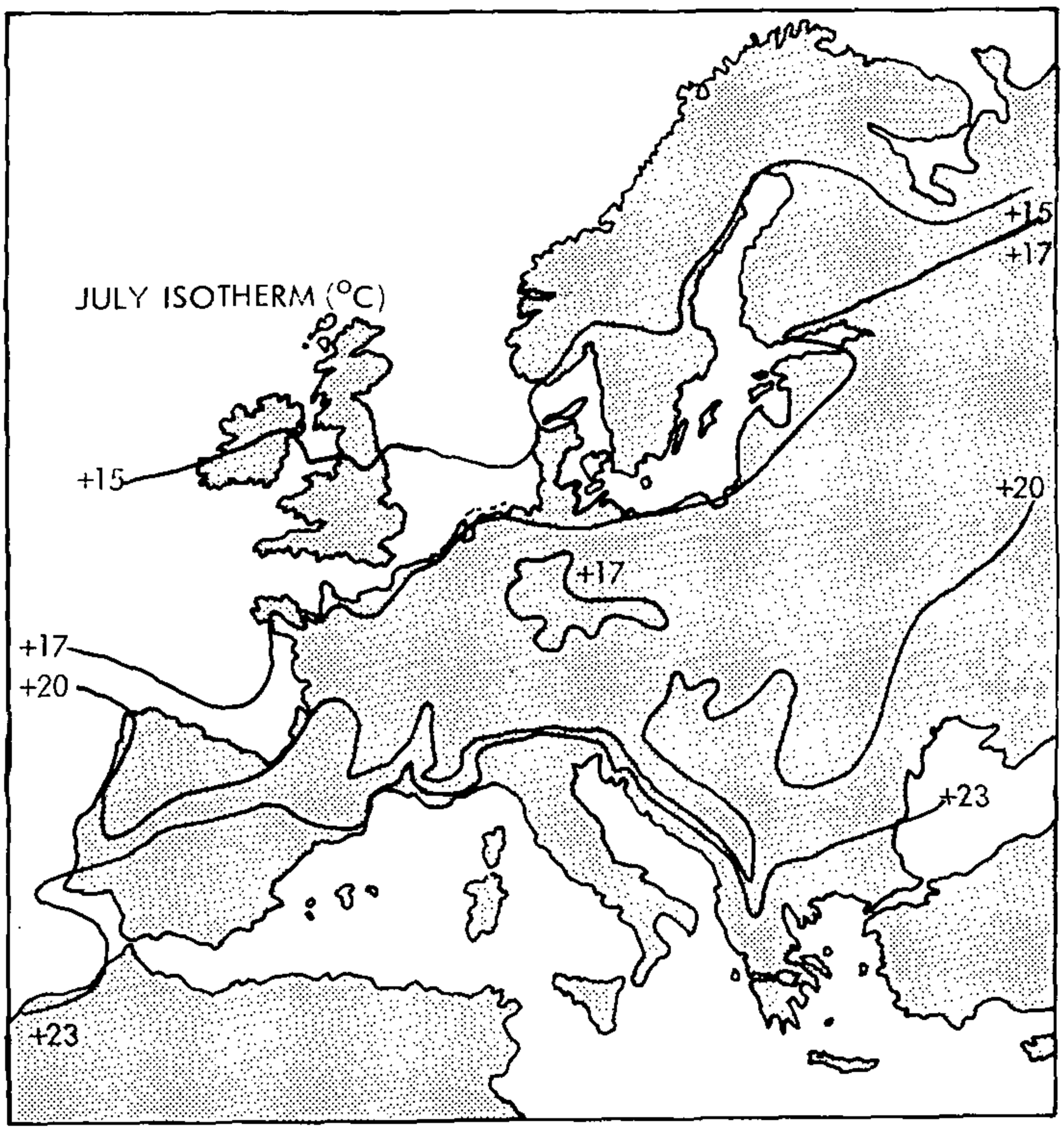

Figure 3. Isotherms (15–23°C) for July in Europe. (Source—World Survey of Climatology. Volume 5; Elsevier Publishing Co.)

Native and exotic species. While the mild climate and ample rainfall encourages the growth of a wide range of plant species, Ireland has a very restricted natural flora as a result of the early breakdown of the land connection with Europe. Consequently, Ireland has only about two-thirds of the native flowering plants

found in Britain. Only three evergreen tree genera (*Arbutus*, *Ilex* and *Taxus*) and thirteen deciduous genera (*Alnus*, *Betula*, *Corylus*, *Crataegus*, *Fraxinus*, *Malus*, *Populus*, *Prunus*, *Quercus*, *Rhamnus*, *Salix*, *Sorbus* and *Ulmus*) are native. However, the climate encourages the growth of a richer and more diverse range of exotic plants than any other country of similar latitude and species from all continents are used to create Irish gardens. Of the most commonly used 1400 tree and shrub species in the country, about 30% were introduced from Asia, especially from Japan and the Himalayas, about 21% from North America, about 20% from Europe, and the remaining 23% are mainly introductions from the southern hemisphere (3).

The naturalising of exotic plants which plays so large a part in the development of Irish gardens probably began with Sir Arthur Rawdon (1662–1695) of Moira, County Down (6). Sir Arthur received a shipload of exotics from Jamaica at Carrickfergus in 1692 and built a hot house at Moira to protect them. Plants propagated there were widely distributed to other gardens in Europe.

Due to historic and economic reasons, gardening in Ireland has evolved more slowly than in England. Interest in gardening and in visiting gardens is increasing, however, and at present many gardens are open to the public. The Irish Tourist Board (Bord Fáilte) recognises that Irish gardens constitute a special tourist attraction with potential for development and expansion and there are now about 40 gardens regularly open to the public, with many more on an occasional basis (1).

Large gardens open to the public occur in all parts of Ireland with the majority lying close to the south and east coasts (5). Hyams (4) describes some of the more notable of these gardens (see Appendix) and traces the evolution of gardening styles and their influence on Irish gardens.

The introduction of large numbers of new plant material from Asia, the Americas, and Australasia in the 19th and 20th centuries had a significant impact on Irish gardens. As so many of the new introductions flourished under the Irish climate, Hyams (4) considers that the wild Robinsonian type garden reached a level of excellence in Ireland rarely achieved elsewhere. A comprehensive inventory of the woody plants in private and public gardens with significant plant collections has been published recently (2).

The suitability of the Irish climate for the growth of trees and shrubs is illustrated in the National Botanic Gardens, Dublin, and in many large private gardens. Rossdohan, County Kerry, is reputed to have the finest examples of tree ferns in Europe; both *Dicksonia antarctica* and the very much rarer and more beautiful *Alsophila tricolor* (syn. *Cyathea dealbata*) are naturalised there. Mount Usher in County Wicklow contains greatly admired specimens of *Pinus montezumae* from south and central Mexico, a very striking

Cunninghamia lanceolata from China and a remarkable collection of eucalyptus species, along with many other Australian plants such as callistemons, grevilleas, and melaleucas. Banana (*Musa basjoo*), *Echium pininana,* and tree ferns flourish in coastal gardens of county Dublin.

Mount Congreve in County Waterford is a garden of 40 ha containing vast plantings of some of the world's most spectacular and beautiful trees, such as *Magnolia campbellii* from the Himalayas and *Embothrium coccinium* from Chile, which gives probably the most colourful display of all the trees that can be cultivated outdoors in these Islands. The National Botanic Gardens, Dublin, have many fine specimens of trees notably the unusual *Cedrus atlantica* 'Pendula' and a fine specimen of the red-trunked, *Arbutus* × *andrachnoides* from Greece. Illnaculin in County Cork contains many plants of exceptional interest such as *Taiwania cryptomerioides* from Taiwan, *Dacrydium cupressinum* from New Zealand, described by Bean in his reference book on "Trees and Shrubs Hardy in the British Isles," as the best specimen recorded in these Islands.

Bean makes frequent mention of other species, especially conifers, that do particularly well in Ireland. Examples are the very large *Abies* spp. such as *A. amabilis* at Castlewellan and *A. nordmanniana* at Powerscourt, the very large *Fitzroya cupressoides* in County Wicklow, an avenue of *Araucaria araucana* at Inistioge in County Kilkenny in which the largest tree is 24 × 3.5 m, a size seldom exceeded by specimens in its native Chile or Argentina, an 11 m high *Cornus capitata* regarded as the finest in these Islands, an 8.5 m high *Cupressus cashmeriana* in County Meath, and 8.5 m high specimens of *Dacrydium franklinii* in County Down and County Cork, these being the tallest of both genera recorded in Britain and Ireland.

While these species come from all five continents, many of them thrive in most parts of Ireland and are not confined to especially favoured areas. Some of our most impressive gardens are situated in the north, e.g. Glenveagh Castle in Counties Donegal and Rowallane, Castwellan Castle and Mt. Stewart in County Down.

The problem of wind exposure. Many of Ireland's best known gardens could not exist without wind protection. Strong winds are frequent and much of the west coast has between 20 to 30 gales per year, when the wind reaches gale force of Beaufort 8 or more (Figure 4). Valentia in County Kerry has an average of 12 days with gales per year while the mean annual wind speed is 6 m/sec compared with 5 along the coast of Brittany and 3 at De Bilt in the Netherlands. Even though these winds tend to be moisture laden, rather than desiccating, exposure is an important element in the Irish climate and horticulturists have to pay much attention to wind shelter and wind hardiness.

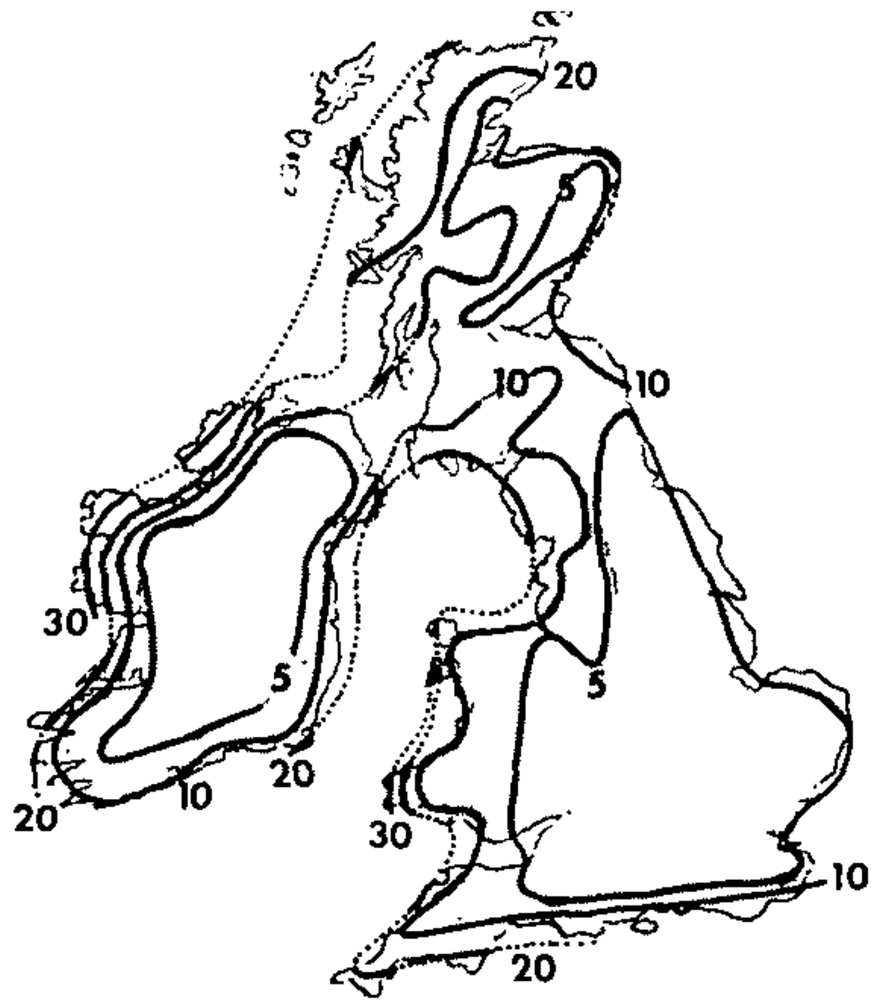

Figure 4. Frequency of gales in the British Isles; days of winds of gale force (Beaufort Force 8 or more). (Source—H. H. Lamb, The English Climate)

Wind adversely affects plant growth in a wide variety of ways including direct leaf and branch damage, increasing transpiration, and lowering air temperatures. In Irish gardens near the coast, saltladen winds in spring and summer can be particularly harmful by causing severe leaf scorch. Salt spray may also be carried many miles inland.

A wide variety of plant species is used for wind shelter. At Rossdohan, County Kerry, *Pinus radiata*, *Cupressus macrocarpa*, *Escallonia rubra* var. *Macrantha* and *Rhododendron ponticum* were used initially, but *Pinus muricata*, which is less easily blown over is now preferred to *P. radiata*. Other plants used for wind shelter include: *Pinus nigra* [syn. *P. nigra* subsp. *austriaca*], *Olearia macrodonta*, Olearia solandri, Elaeagnus macrophylla, Elaeagnus *ebbingei*, *Griselinia littoralis*, *Tamarix* spp., *Ulex europaeus*, *Phormium tenax*, *Salix caprea* and *Alnus* spp.

The problem of weed control. The climatic and soil conditions in Ireland that provide such favourable conditions for the growth of exotic trees and shrubs are naturally even more favourable for the growth of indigenous weeds. Many weed species such as *Poa annua*, *Stellaria media*, and *Senecio vulgaris* can grow and seed throughout the year. Initially weeds in Irish gardens were controlled by manual and mechanical means. These methods are highly inefficient because many species, particularly *Poa annua*, after being hoed or hand pulled, promptly reroot in the highly humid environment. At present there is a wide range of herbicides available which can suppress the development of seedling weeds for long periods and give better control of perennial weeds than soil tillage. Herbicides are relatively cheap compared with the cost of hand labour.

Just as conditions in Ireland proved to be unexpectedly suitable for the new Robinsonian style of gardening introduced in the 19th century, so the Irish climate and soil have been found to possess significant advantages for chemical weed control compared with many other countries. Simazine, the cheapest soil-acting herbicide available at present, controls a wide range of common annual weeds. It is only effective as a selective herbicide when applied under moist soil conditions. Normally simazine will persist close to the soil surface but on light sandy soil or in soil deficient in organic matter, simazine may leach downwards and may be phytotoxic. Most soils in Ireland have more than 4% organic matter and simazine has proved highly satisfactory for weed control and is safe under a range of conditions in many parts of the country. Moreover, the moist summers and mild winters provide suitable conditions for the activity of soil microbes. Consequently, there have been fewer problems arising from the build-up of residues of soil-acting herbicides in Ireland compared with countries with drier seasons and colder winters.

Simazine and many other soil-acting herbicides may be used at any time of the year, assuming moist soil conditions, and will control germinating weeds for many months. This allows major weed control activity to be shifted from the busy late spring/summer period to other times of the year when labour is more readily available.

A 1.5 ha amenity area in North County Dublin has been used as a "herbicide-garden" since 1969 to evaluate the long-term effects of herbicides on ornamental trees and shrubs and on soil conditions. The garden contains representatives of over 200 plant genera, mainly shrubs. The soil is a medium loam derived from Cambrian shale and quartzite, containing approximately 25% clay and 4.5% organic matter in the top 75mm.

Usually two applications of a triazine herbicide (simazine or atrazine) were applied as an overall treatment each year from 1969 to 1986. Two applications of simazine at 1.7 kg a.i./ha per annum were applied between 1969 and 1976 and between 1981 and 1986, and two applications of atrazine at 1.7 kg a.i./ha between 1977 and 1980, except in 1970 (3 applications) and 1979 (1 application). Other herbicides were used as spot treatments against specific weeds (7). To reduce the risk of a build-up of resistant biotypes, a determined effort was made to control any weeds that survived the routine application of triazine herbicide before they shed their seeds. This necessitated the use of a range of different herbicides supplemented by some hand weeding.

Following the extensive and repeated use of herbicides on the same area for 17 years, the main conclusions are:

(1) Herbicides provide a practical, highly successful and impressive means of maintaining an amenity area. In contrast to experience elsewhere no woody plant, established for at least one

year, has been found to be susceptible to simazine or atrazine injury. While the prevailing soil conditions assisted the safe use of herbicides, soils equally suitable for chemical weed control occur in many parts of Ireland.

(2) Although triazine herbicides (simazine or atrazine) have been applied at 1.7 kg a.i./ha usually twice a year for 17 years, there is no evidence of any build-up of triazine-resistant weed biotypes. This was almost certainly due to the high level of weed control which prevented most weeds from seeding.

(3) Weed populations have been reduced and the time required for control has decreased.

(4) There has been no deterioration of soil structure apart from the formation of a thin crust (ca 10mm thick) at the surface. On this soil type, the crust caused no problems with water run-off or erosion and has not had any adverse effect on soil aeration.

(5) There is no evidence of any build-up of phytotoxic residues of triazine herbicides after repeated application for 17 years.

Although some herbicides, notable glyphosate, are adversely affected if rain falls within 6 hours of application, chemical weed control in general is favoured by good growing conditions.

Herbicides are used extensively in a few large Irish gardens, such as Mount Congreve and the National Botanic Gardens, and for controlling weeds in paths and uncropped areas in many others. Results obtained in North County Dublin suggest that chemical methods could be used much more extensively for the maintenance of amenity areas and to ensure the survival of large Irish gardens in a period of steadily rising labour costs. Herbicide technology can overcome a major maintenance problem and free time for more constructive horticultural activities. Probably most important of all, the use of effective chemical methods can eliminate the struggle against year-round weed growth which has done so much to sap enthusiasm for amenity land management.

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APPENDIX

Irish gardens described by E. Hyams (4).

Annes Grove, Co. Cork
Ardsallagh, Co. Tipperary
Birr Castle, Co. Offaly
Castlewellan, Co. Down
Fota, Co. Cork
Glasnevin, Co. Dublin
Glenveagh Castle, Co. Donegal
Ilnacullin, Co. Cork
Mount Congreve, Co. Waterford
Mount Stewart, Co. Down
Mount Usher, Co. Wicklow
Powerscourt, Co. Wicklow
Rossdohan, Co. Kerry
Rowallane, Co. Down

ALPINES WORTH GROWING

J. G. D. LAMB
Woodfield, Clara,
County Ofaly, Ireland

When asked to speak on alpines worth growing, one is immediately in a dilemma, so numerous are the plants worth growing in the rock garden. One can only make a selection—and a selection must be largely subjective. There are some huge genera: gentians, saxifrages and primulas, to mention only three, which have contributed so many lovely species to our gardens that each genus alone could fill the 45 minutes allotted to this talk.

So here is my selection. I have avoided, on the one hand, those rather rampant but worthy plants represented by, for example, aubrietia, arabis and cerastium (though there are a few aristocrats amongst these) and on the other, those choice but exacting plants that demand culture in an alpine house, like the high alpine androsaces and dionysias. I love them all, but I have to come down to earth, and I have endeavoured to choose from those that I consider choice enough for the keen plantsman, but not too difficult to grow and propagate. Above all, they are plants that I have been able to grow and enjoy in the open garden.

Some of the earliest spring bulbs are happily placed in the rock garden. One of the first to flower, in February, is *Narcissus cyclamineus*, and a long lasting flower it is too. I find it does poorly in alkaline soil, but flourishes and seeds itself in peaty soil, as does the delightful hoop petticoat daffodil (*N. bulbocodium*). The hardy cyclamen, too, brings colour to the rock garden early, and again later. The earliest is *Cyclamen coum* in a variety of shades. I must digress here to show you how it has naturalised in a County Wicklow garden, to give a pink haze through the lawns. *C. repandum* does so well with me that I have taken it out of the rock garden and naturalised it under beech trees. The secret, I think, is to plant the corms deeply.

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From North America come several lovely trilliums, especially *Trillium grandiflorum*, robust enough for the open ground, but the tiny *T. nivale* I grow in a stone trough. Also American are most of the delightful dog's tooth violets, or trout lilies. One of the most satisfactory is *Erythronium* 'White Beauty'. Still on the bulbs and tubers we can touch on the fritillaries. Some are difficult, but the Snake's Head (*Fritillaria meleagris*) and *F. pyrenaica* are very willing to flourish and increase. The dark colouring of the latter gives rise to the unkind name 'Mother Ugly', but the whole poise of the plant is attractive and the interior of the flower is a lovely shining olive green.

The genus *Primula* is one of the largest and most important in our gardens. I do not intend to discuss the larger candelabra types nor the small cushion species, but *P. rosea* can be mentioned for its earliness and colourful show in any damp corner. Among the European alpine types one of the favourites is *P. marginata*, a variable plant but always free flowering, and attractive in foliage, having powdered edges to the toothed leaves. A fine form or hybrid is *P.* 'Linda Pope'.

Anemones, too, are a big group. The furry flowers and silken seed heads of the pulsatillas give double value in the garden. Not so easy, though, is the so-called blue buttercup, *Anemone obtusiloba* var. *patula*. We are in the thick of the important families in the garden now. Of the pinks I have only time to mention *Dianthus* 'Mars'—dwarf, compact, and long flowering.

Crucifers, too, give us many good rock garden plants, such as *Aethionema grandiflorum* and the more familiar *A.* × *warleyense* [syn. *A.* 'Warley Rose']. Drabas give us a few garden worthy plants, such as *Draba rigida* [syn. *D. bryoides*], with green cushions and golden flowers. We are told that *Morisia monanthos* [syn. *M. hypogaea*] has the curious habit of burying its own seedpods, but my plants never set seed. Perhaps cross-pollination of different clones is necessary. No matter, though, as it is so easy to propagate by root cuttings.

To many, gentians are *the* alpine plants. Fortunately, *Gentiana acaulis* does flower well with me. How does one keep *G. verna* in good condition indefinitely? After about three seasons of flowering my plants deteriorate, but by sowing fresh seed in the autumn, germination is prolific the following spring. There are many other good gentians, easy and not so easy. I mention just one more, *G. loderi*, flowering in late summer. It has never set seed with me and I take cuttings in spring after the fashion of chrysanthemums.

A bulb that is a great value over a long period in late summer is *Rhodohypoxis*, but especially good is the red cultivar 'Albrighton'. The only trouble is mice during winter.

From numerous sedums I pick only one, *Sedum spathulifolium*, well-behaved and attractive, especially 'Purpureum', the wine

coloured leaves being dusted with white, the more so in 'Cape Blanco', also known as 'Capablanca'. [This is probably *S. spathulifolium* subsp. *pruinasum*, (Bot. Ed.)] Saxifrages are as important as gentians and primulas, but despite this I mention only two: *Saxifraga longifolia* 'Tumbling Waters', which has decorative rosettes and spires of snowy flowers. *S. grisebachii* depends on the red-coloured stems and calices to set off its small pink flowers.

Daphnes do well on my limy soil, including the sweetly scented *Daphne cneorum* and the more compact *D. arbuscula*. *Polygala chamaebuxus* is a small shrublet, variable in colour, valued for flowering over a long period, even into winter. While on the subject of dwarf shrubs for the rock garden we can glance at *Cytisus* × *kewensis*, one of the best of the dwarf brooms. Owing to lime in the soil I cannot grow dwarf rhododendrons or other acid requiring plants without making a special bed. In this way I grow *Cassiope mertensiana* var. *gracilis* and *Kalmiopsis leachiana*, so like a dwarf rhododendron or kalmia. *Lithodora diffusa* 'Grace Ward' is grown flowing down the side of such a special bed. Elsewhere in the garden I console myself with the equally blue, but lime tolerant, *Moltkia petraea*.

Ramondas do well in our moist climate, even if planted on the flat. *Ramonda myconi* is quoted for propagation by leaf cuttings, but this would seem scarcely necessary with *R. nathaliae*, so prolific is it by offsets. Quite different conditions: gritty soil and full sun, suit the alpine woodruff, *Asperula gussonei:* [syn. *A. suberosa*], with clouds of pink flowers over silvery foilage.

Columbines and campanulas are two familiar genera that contribute to the rock garden. Unlike so many of its larger relatives, the dwarf *Aquilegia discolor* breeds true. Some of the campanulas are a bit rampant, but *Campanula elatines* var. *garganica* in all its forms, though easy, is well behaved. The cultivar 'Erinus' is familiar, but less well known is the form of Irish origin called 'W. H. Paine', with a white eye to the flower. Violas, too, contribute some choice species to the alpine garden, such as *Viola tricolor* subsp. *subalpina* [syn. *V. saxatilis*]. *V. elatior* is quite different in habit, stiffly upright and with lilac flowers. Though *V. hederacea* is slightly tender, I admit it to the rock garden as the dark blue and white flowers go on and on into late autumn.

It is sometimes thought that a rock garden lacks colour in late summer and autumn, but there are many flowers for this season. I have not mentioned the gentians of the sino-ornata group. With them we may plant several *Cyananthus* species. *Cyananthus microphyllus* forms a ring of blue periwinkle-like flowers in August. Several good geraniums flower late, like *G. dalmaticum*. Roscoeas are so late in coming up that they may be thought dead, but their orchid-like flowers appear safely in July, yellow in *R. cautleoides*, purple in *R. humeana*.

Though tall for all but the outskirts of the rock garden, I could not omit the meconopsis, especially the famous blue kinds, such as *Meconopsis* × *sheldonii* 'Slieve Donard'.

Finally, though I have concentrated on easy-going plants, I cannot resist mentioning two that I have struggled with. The first is *Campanula zoysii,* with its extraordinary flowers crimped at the mouth, which have been described as tiny blue torpedoes. Though reputed to be a martyr to slugs this was not the trouble in this case. Instead, the plant flowered itself to death. The plant I conclude with is another oddity, *Calceolaria darwinii*. The strange flowers are borne on stems only an inch or so high. I am constantly on the brink of losing it, as plants are apt to wither off for no apparent reason. I wonder if it is a virus, for this calceolaria is a favoured food of the greenfly.

PROPAGATION OF CHOICE ALPINES

DUNCAN J. SMALL

Anglia Alpines

Needingworth Road, Bluntisham, Huntingdon, Cambs.

Anglia Alpines is a wholesale alpine nursery. The ultimate aim of any propagation enterprise is to produce a plant that is saleable at the right time. When wholesaling to retail customers this generally means a good potful in flower. In order to achieve this, potting and propagation must occur at the appropriate time, this being dictated by the sales period.

The natural conditions in which mother plants produce cuttings may not fit this desired production timing, but manipulation of the mother plant by altering its environment, and pruning as well, can be used to achieve this goal.

Another method is to take cuttings when optimum conditions prevail and, by manipulating the rooting environment, ensuring that the plant is ready for potting when required. For example, with *Helianthemum* spp., semi-ripe cuttings taken in September will root in a cold frame and be ready for potting in April. For later potting in May or June, softwood cuttings from forced mother plants can be rooted under glass with bottom heat.

In the commercial propagation environment the methods used are not necessarily the only ones possible, but are ones which give the greatest multiplication rate, or are most suited to a particular production cycle—the most cost-effective in each circumstance.

If you study a treatise on the propagation of alpines, there are as many different methods as there are plants grown, but for

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streamlined management as few different regimes as possible are employed. At Anglia Alpines three principal methods are used:

1. Glass and basal heat
2. Cold glass or polythene
3. Cold frame

A standard compost is used throughout propagation, where suitable, as well as a standard tray size, to enable ease of handling and space allocation.

As we have just mentioned, there is a wide range of desirable alpines. Many of these, although easy to propagate, are more difficult to grow on to saleable specimens in a commercial environment. These become specialist collector's items. The genera I have chosen to illustrate alpine propagation are those which are popular with plant buying customers, and also display the use of a wide range of propagation techniques.

CAMPANULA

Campanula is a genus we grow in large volumes in a wide variety of species and cultivars, as they give us flowering subjects all summer in varying shades of blue through to white.

Seed-raised cultivars are used where suitable subjects are available; otherwise, all are propagated from softwood cuttings. Seed is commercially available in regular quantities of a good range, and as this is an economical and easy propagation method we use it where we can.

Seed is sown in standard seed trays, containing 75:25 peat:fine grit compost, which also contains a small amount of fertilizer and lime. After sowing, seeds are not covered. A germination cabinet is used to start seeds off. This has a thermostatically controlled heating element to maintain a constant growing temperature. For *Campanula* spp. a stable but not too high temperature is required; temperatures above 21°C tend to inhibit germination. Once germination has started trays are removed from the cabinet and seedlings grown on with basal heat until large enough to handle. Pricking out is done into modular trays containing the same compost as the seed trays, but with a higher level of fertilizer. These are grown on in a frost-protected, or cold tunnel, depending on the time of year, until the plants are large enough to pot.

We have carried out some experiments with direct seeding of modules, with a pinch of seed per cell. This has proved successful except that an extensive germination area is required to accommodate the large number of modules produced.

Many of the named cultivars of *Campanula* spp. cannot be produced by seed, and so cuttings are used. Suitable cutting material is readily produced from the rhizomatus growth of these plants, rooting occurring from the etiolated base.

The action of taking cuttings encourages further production of suitable cutting material. Cuttings are taken by passing a knife about ¼" below the soil surface severing the shoots which can then be easily lifted.

As with the majority of alpine cuttings on our nursery, module cells are used with a 50:50 peat:perlite compost, which contains a base dressing of trace elements and superphosphate. Basal heat under glass, or in a tunnel, is applied in the early part of the year, but unheated structures later in the year give good rooting.

Growth or holding of rooted cuttings is achieved by supplementing the base dressing in the compost with liquid feeds of varying N.P.K. ratios.

SAXIFRAGA

Saxifraga plants comprise a large part of our early year sales as the wide variation of flower colour and foilage type lend themselves to production in volume.

The saxifrages grown at Anglia Alpines fall broadly into 3 catagories: (1) mossy types, (2) kabschia types, and (3) encrusted types. For propagation purposes we treat these as two groups, putting kabschia and encrusted types together.

As these plants flower early in the year, propagation from cuttings occurs once flowering has finished in June or July. The cutting material of these plants is generally small and slow growing and a large propagation period is needed, often 1 year from rooting to potting, and a further year to sale. Cuttings are stuck into coarse fertilized sand, either directly in a cold frame or in seed trays.

We have found *Pythium* spp. to be a problem in the propagation environment of these plants, especially after rooting. A routine spray programme plus fertilizer in the rooting medium to prevent stress after root initiation has largely cured this problem.

Kabschia saxifraga cuttings are very small and thus difficult to keep positioned in a rooting medium. In order to help with this, mother plants are forced using higher than ambient temperatures and shading to produce elongated shoots which are easier to handle.

Encrusted saxifraga types are rosette-forming, and although easier to handle, have a very short stem which needs careful insertion to get good contact between its base and the rooting medium, thus sand is used as a medium as the small particles give good contact with the cutting's base.

One problem we have encountered with both these saxifraga types is the lodging of weed seeds in the rosettes and fine leaves. The germination of these seeds in the propagation environment is rapid, and cuttings can be quickly engulfed. To prevent this, apart from

keeping mother plants away from weed seeds, has been to wash cuttings to dislodge any seeds prior to insertion.

Mossy saxifraga subjects fit more conventionally into the propagation systems used for other alpines on the nursery. Individual rosettes are cut off with a long stem to enable insertion into a cutting medium (50:50 peat:perlite) in modules. Young, fleshy growth roots readily and mother plants forced under glass are used to produce these early in the year. This allows potting to take place early and a saleable plant is produced for autumn or following spring sale.

SEDUM

Sedum spp. cover a wide range of plant types, including evergreens, herbaceous perennials, and monocarps. Accompanying this range of plant types is a correspondingly wide range of propagation methods. The main ones used at Anglia Alpines being: (1) division, (2) direct sticking into pots, (3) conventional cuttings, and (4) seed.

Division. The mat-forming species lend themselves to division as the creeping shoots root into the ground as they travel. As these are non-woody subjects, these mats easily pull apart and portions of plant from one shoot to a handful can easily be planted.

Direct Sticking. Another way of handling the mat-forming species, which also works for many of the clump forms, is direct sticking into the market container. A few shoots from the mother plant are broken off and bundled together and their bases firmed into the compost: A 3 in. pot can be ready for sale in 2 to 3 weeks. The ability of some of these sedum species to root so readily can cause problems. *Sedum acre,* the yellow stonecrop, has become a major weed in some orchards. Portions broken off by birds, people's feet, and tractor tyres root where they fall, spreading the problem.

Cuttings. The newly emerging shoots of the herbaceous perennial types root readily from the etiolated base, if taken as conventional cuttings. A supply of suitable cutting material can be maintained by keeping mother plants cut down.

Seed. Many of the *Sedum* spp. can be raised from seed but as they root so readily and form saleable plants quickly, seed propagation is a method we employ for the herbaceous perennial types only. Seed sown in seed trays on a peat/grit compost, germinates rapidly at 15 to 18°C, and can be pricked out for growing on to potting size.

Alpines offer a wide scope for the propagator to use a range of techniques, and although much mystery has been attached to alpine propagation, it is just the application of the principles used in shrub and herbaceous perennial production, scaled down to accommodate the small nature of the propagule.

PRIMROSES AND VIOLETS: WHAT'S NEW!

L. NIGEL COLBORN

Careby Manor Gardens
Careby, Nr. Stamford, Lincolnshire

Our nursery is very small indeed. It will be even smaller next year for we are dropping our mail order service. However, we do pride ourselves on having a reasonably comprehensive collection of unusual plants in the gardens at Careby and have particular interest in some of the more old-fashioned 'Cottage' type plants. Furthermore, these types of plants are becoming very fashionable today.

PRIMROSES

For the purpose of this presentation, primroses means members of the genus *Primula* from Europe and their cultivars. Asiatic groups and modern hybrids such as 'Crescendo', polyanthus and 'Spectrum' primroses are not under consideration here. You must remember that we cater to a particular type of gardening where bright colours and overlarge flowers are regarded with a great deal of suspicion, unless of course they are rhododendrons. To be sure, your jazzy modern hybrids have their place, but to compare them with such gems as *Primula* 'Lady Greer', or the dark-leaved *P.* 'Garryarde Guinevere', would be as banal as trying to line Mozart up with "Wham" (I dare not mention the "Boom Town Rats"!). That is not to say that all our primulas are antiques. We are even breeding a few, for it is the character of the plant that matters, not the age of its pedigree—compare David Austin's English roses as another example where 19th century characteristics are used with modern breeds.

Culture. First the true species—*Primula veris, Primula vulgaris, Primula farinosa*, etc. We propagate these from seed, taking care to keep stocks as pure as possible where unwanted hybridisation may occur. The same techniques seem to work fairly well for all the European primulas; my private rule is that if you can succeed with wild cowslips this way, you can manage pretty well everything else.

Seed is gathered as it ripens through the summer and stored until September when it is sown. A gritty, peaty mix (it varies with the species) is used and this is firmed down *after* sowing the seed. It does not seem to be necessary to cover the seed, but a sprinkling of very coarse grit (⅛" is not too much), helps to inhibit the growth of algae. The grit may also help to protect the young seedlings from excessive dampness as well. The pots are weathered in a cold frame which is only covered during prolonged periods of very wet weather. (Frost and snow is no problem). Germination is usually complete by the end of March. We prick out into seed trays and then

into a Rapidex system 3-in. square pot. The following spring this will have produced a single rosette plant with one large flower spike and at least one secondary bud, i.e. it is ready for marketing.

Hybrids. The *P. juliae* hybrids are propagated by division. All but the most vigorous plants are split once a year, but only in mid-summer. However, we do divide right down to the smallest rosette and, at the same time, remove as much of the rhizome as possible without destroying all the roots.

Plants of *Primula auricula* and its allies (*P.* × *pubescens, P. marginata* and all the other leathery-leaved species) establish more slowly from divisions, so we try to split them a little sooner in the year. The only disadvantage of early splitting is that it can inhibit seed collection.

Overwintering. This seems to be the area where most people (and we are no exception) seem to come unstuck. All the juliae primulas are fully hardy and will tolerate temperatures well below freezing for a prolonged spell. However, they will not tolerate alternate freezing and thawing—neither do they tolerate water round their necks. Here are some observations made last winter. Cowslips in Rapidex pots in an open frame froze solid. The covering of snow was helpful while it was there, but with a slow thaw in sunlight at midday, I observed that many pots were frozen an inch below the top, but had water unable to drain away, standing on the compost surface. This froze each afternoon and many cowslips were lost. Potted primulas died in the shade tunnel, while their neighbours in the same tunnel, but planted in the ground, thrived. Thus our routine is to place newly split plants into the shade tunnel then move them into a shaded polytunnel from mid to late November onwards.There they stayed last year until early May. There were few losses although we kept the plants cruelly dry. There was no sign of life in any of the pots until long after the end of the tough winter, but almost every rosette came to in time for the Harrogate Spring Show. Thus, the moist shade until winter begins, then dry shade seems to work best for us.

VIOLETS

Now to that other family near to my heart—Violaceae. People often ask me what the difference is between a pansy and a viola. I usually answer, "All pansies are violas, but not all violas, pansies." Not very helpful really. I realise that pansy growers have their own special terms but the plants we will be briefly discussing are several members of the genus, *Viola,* but will exclude pansies. Clear?

For what it is worth (for the total market potential could probably be tucked away in the corner of one of Mr. Bloom's offices), we grow a wider range of sweet violet cultivars than anyone else. I am referring to the little scented flowers that

Victorian and Edwardian gents used to buy from flower girls to give to their wives, hoping to salve their consciences after philandering. Napoleon gave them to Josephine when it was not "not tonight."!

There are thirty to forty cultivars left in cultivation today and they are enjoying something of a comeback. Of that number about a dozen are really worth growing and the following make excellent plants:

Mid-blue—	'John Raddenbury' (a successful cutting violet). 'Saint Helena' (ground cover only)
Deep-blue—	'Baronne Alice de Rothschild' (best scent) 'Czar' (best vigour)
Violet—	'Norah Church'
Purple—	'Amiral Avellan' (superb sharp scent, best all rounder)
Pink—	'Coeur d'Alsace' (large flowers, clear pink) 'Rosina' (vigorous)
White—	'Rawson's White

The only truly hardy Parma violet is 'Swanley White' or 'Compte de Brazza'. These plants are split in late summer when conditions are not too dry. It is easy to take cuttings from runners, but it saves time if each runner has a tiny amount of root. We discourage the plants from producing further runners during autumn and this promotes flowering in spring at selling time. Like primroses, sweet violets are almost impossible to sell to the general public unless they are in flower.

When you try growing sweet violets commercially you can see why they almost became extinct. They require a lot of attention and tend to look horrible in containers. Red spider mite is the worst pest for it curls the leaves, eventually causing gall-like growths. In dry weather this can be fatal, but at the best of times it is inclined to disfigure the foliage. We spray at regular intervals with a dilute mixture of Dimethoate, Rovral to allay botrytis, and very weak foliar feed. Sweet violets are voracious feeders. The other pest is a kind of mosaic virus which will wipe out quantities of stock very rapidly. It is aphis-borne, so the Dimethoate is useful in this respect too.

If grown—as most of them are these days—as a ground cover in mixed planting schemes (especially under shrubs), they need little attention after planting out. However, for cut blooms it is necessary to treat them rather like strawberries. All runners must be removed, feeding should be generous, and they should never become overheated or too dry. Under these conditions most cultivars will flower profusely in spring but sparingly from September onwards.

OTHER VIOLET SPECIES

Apart from *Viola tricolor* types (a bit nearer to pansies), there are many violets which make first class garden plants. Classification of many highly variable species has proven baffling to even the most experienced experts and I have several plants which defy identification. One, a cream dog violet flowers perversely from July to October!

Viola cucullata is a fine plant and can be seen effectively used at Sissingburst in the spring garden, where it has seeded well. There are some first rate variants, such as *Viola* 'Freckles', with mottled blue and white flowers looking for all the world like tiny Spode crocks, and *Viola cucullata* 'Rosea' a rather liverish pink.

Other North Americans, like *Viola septentrionalis* and *V. sororia* show up well and require less shade than our own natives. *Viola rupestris* 'Rosea' (well, it is not actually *Viola rupestris*, but more likely a form of dog violet, *Viola rivinana*) comes in several shades and is a rapid spreader.

Viola elegantula [syn. *V. bosniaca*]—a bright mauve sun-lover from East Europe.

Finally, the tree violet, *Viola elatior*, which can be treated as a straightforward herbaceous perennial and produces flowers at 18 inches. The colour of the blooms is quite delightful—pale Cambridge blue and white.

All the foregoing are easily propagated from seed, but the North Americans have fleshy rhizomes which can be snapped off and potted at will.

Finally, the "tricolors". The ones we grow are, again the older style plants that belong in old-fashioned schemes. One of the best loved is 'Jackanapes' (said to have been introduced by Gertrude Jekyll, but I have a feeling they were around a long time before that). Raising these plants from seed is unreliable, unless one has facilities for keeping the stocks pure.

Most of our stocks are grown from cuttings. These are taken at any time during the growing season and rooted on the mist bench. It is impossible to take anything without a flower bud, but we do trim off as many blooms as we can see. Sometimes we use rooting powder (Seradix: pink strength), but usually rooting will take place in about three weeks without it.

Heat stress can be a problem with our system, as we rely on mist propagation, heavily shaded in a polytunnel, so temperatures are inclined to be about ten degrees higher than the maximum desirable in June. The rooted plants are potted directly into 3" Rapidex pots in our usual universal compost of roughly 50–60% peat (Irish of course—what else???), 10% perlite and the rest coarse sand and a little grit.

SUMMARY

This, then, is a brief sketch of how we grow some of our primulas and violets at Careby. The old-fashioned versions of these popular spring plants are easy to propagate conventionally. As many of them hybridise so readily, it is safest to use vegetative means if stocks are to be produced which are true to name.

INFLUENCE OF THE ENVIRONMENT ON ROOTING *DAPHNE ODORA* CUTTINGS

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Abstract. Analysis of the environmental influence on volume rooting of Daphne odora revealed that irradiance and night temperature requirements must be fulfilled for successful *in vitro* rooting to take place.

INTRODUCTION

Within the commercial micropropagation industry competition demands that all efforts be made to optimise the productivity of the laboratory and the quality of the propagule. The very high cost of research has meant that work at this laboratory on specific difficulties has been done on high value ornamental plants from the sale of which some rapid return on investment can be achieved. The work on *Daphne odora* was done to identify some of the causes of inconsistent rooting response which have been observed in these and other woody plants at this laboratory.

From work on *Daphne* and other species it had been observed that a rooting treatment successful to a high percentage at one point in time might not yield a similar result even when repeated only a month later. From various experiments it appeared that neither the genotype of the subject nor human error in media manufacture or culture handling was responsible for the major part of rooting inconsistencies. Rather, variations in response appeared to be related to variations within the environment of the growth room itself.

It was decided, therefore, that a more detailed examination of the growth room environment was required to examine temperature and irradiance influences on rooting. For this purpose, production growth room rooting responses were compared to rooting

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It was decided, therefore, that a more detailed examination of the growth room environment was required to examine temperature and irradiance influences on rooting. For this purpose, production growth room rooting responses were compared to rooting

within growth cabinets providing small measured temperature and irradiance variations.

D. odora is described by Brickell and Matthews (3) as a shrub which grows up to 4 feet in height. It is a flowering evergreen and is hardy in many parts of Britain.

MATERIALS AND METHODS

Shoot tips up to 10cm in length were taken from containerised glasshouse-grown stock plants. These shoots were trimmed of leaves and cut into sections 2cm in length which included one or two buds. The sections were sterilized in a 15% solution of Domestos, a proprietory bleach, for 15 minutes before being rinsed in sterile water. Following sterilization, bleach-damaged tissue was removed in a sterile laminar air flow cabinet, and the explants were placed on multiplication media. Culture vessels were clear plastic disposable tubs (Neo Plants Ltd) 7.8cm in diameter and 5.5cm in height and contained 50ml multiplication media consisting of the salts and organics of Lloyd and McCown (6) woody plant medium (WPM) and sucrose (30 gl^{-1}), agar (7.5 gl^{-1}) and benzylaminopurine (BAP) (0.5 mgl^{-1}). The pH was adjusted to 5.7 before autoclaving using dilute NaOH. Media was sterilized by heating to 121°C for 15 minutes, in ½L or 1L bottles and was poured into tubs shortly before setting.

Following introduction to culture the shoots were routinely subcultured every 4 weeks for more than 6 months. Rooting experiments began when enough shoots were available. For rooting work, shoot tips 1cm in length were taken from multiplying cultures and placed on rooting media. All multiplying cultures and cultures rooted in the growth room were provided with a 16 hour day with temperatures between 19° and 26°C and with 40 to 55 $\mu em^{-2}s^{-1}$ irradiance measured inside the culture from warm white fluorescent tubes.

Dark-treated shoots were transferred to rooting media and placed in continuous dark for 4 days before being moved to 16 hour days.

Table 1. Rooting of *Daphne odora* cuttings on F14 Medium in four different production scale runs.

	Batch 1	Batch 2	Batch 3	Batch 4
Number of tubs	191	103	9	70
Number of shoots	3125	1680	106	1390
Total rooted	1250	543	78	1122
Total percent rooted	40	32	73	80

Rooting of *D. odora* cuttings was under as similar conditions as possible. Differences among treatments are the time rooting transfer was made and the area of the growth room used.

For the rooting experiments analysed in Tables 2 to 4 two Leec

growth cabinets were used (Leec Laboratory and Electrical Engineering Company, Nottingham NG4 2AJ, UK).

These provided temperature and daylength control and, with warm white fluorescent tubes mounted vertically at the rear of the cabinets, provided irradiance that ranged from 2 to 64 $\mu em^{-2}s^{-1}$ at different points within the cabinet. Shoots given dark treatment were placed in darkness immediately following transfer to rooting medium at a temperature of 22–26°C.

Irradiance was measured with a unit from Lambda (λ) Instrument Corporation, supplied by T. J. Crump, Scientific Instruments, Wickford, Essex, Model L1/185 in units of $\mu em^{-2}s^{-1}$. Temperature, which was measured by an Edale Multiprobe Thermometer loaned by the local branch of the Agricultural Development and Advisory Service (ADAS), also varied from point to point within the cabinet; from 16.5°C to 22°C at night and 16.5°C to 25°C in daytime, but was found to be constant (± 0.5°C) throughout the experiment in any particular position. Day temperatures, night temperatures, and irradiance were measured within all culture vessels for the experiments analysed in Tables 2 to 4.

Table 2. Combined analysis of variance for irradiance, day and night temperature, on the time to 10% rooting (T10) of *Daphne odora* cuttings.

Terms	DF	Mean Change	VR	
Modifications to model				
+ °C N	1	591.671	88.03	p = 0.001
+ °C D	1	77.614	11.55	p = 0.01
+ IRR	1	8.257	1.23	NS
Residual	136	6.721		

Table 3. Combined analysis of variance for the effects of irradiance, day temperature and night temperature, on rooting *Daphne odora* cuttings at day 24.

Terms	DF	Mean Change	VR	
Modifications to model				
+ °C Night	1	51.470	13.44	p<0.001
+ °C Day	1	12.608	3.29	p>0.05 NS
+ Irradiance	1	35.912	9.38	p<0.01
Residual	136	3.831		

Shoots taken from multiplying cultures were placed in a rooting medium containing ½ strength salts of WPM with full organics, sucrose (20 gl^{-1}), agar (7.5 gl^{-1}), and the plant growth substances naphthaleneacetic acid (NAA, and/or indolebutyric acid (IBA). The rooting media was also adjusted to a pH of 5.7 and sterilized before pouring into clear plastic culture tubs. All statistical analyses were carried out using the Genstat package developed at Rothamstead Research Station.

RESULTS

During preliminary experiments a rooting percentage of 100 was achieved in growth room conditions providing a 16 hour day. In subsequent unreported work the cause of variable responses seen in Table 1 was shown not be to due to human error.

Tables 2 to 4 are taken from an experiment to identify the most likely cause of variable rooting, assuming no human error or genotype variation. Using growth cabinets (see Materials and Methods), 140 culture tubs containing 22 shoots each were treated to conditions of measured day temperature, night temperature, and irradiance. Rooting was assessed daily in each tub from the first sign of root emergence to the end of the experiment at day 24.

In analysing the results the proportions rooted were transferred into a logit scale and regressed against time. The time to 10% rooting was estimated for each tub from these regressions to give an indication of start time. Both this and the slopes of the lines were regressed against day temperature, night temperature, and irradiance. Day 24 was used as a measure of the final response and the results were analysed with respect to day temperature, night temperature, and irradiance. The complete analysis is shown in Tables 2 to 4, inclusive.

The analysis of the results identifies some of the primary causes of rooting variation as being due to night temperature and irradiance. Whilst reducing the time to 10% rooting (Table 2), higher night temperatures also very significantly influenced the final percentage rooted at Day 24 ($p<0.001$, Table 3). Conversely, irradiance played no part in the time to 10% rooting, but increasing irradiance increased the final rooting percentage($p<0.01$, Table 3).

Table 4. Combined analysis of variance for irradiance, day temperature and night temperature, on rooting rate of *Daphne odora* cuttings.

Terms	DF	Mean Change	VR	
Modifications to model				
°C Night	1	0.7681	3.39	NS
°C Day	1	0.3847	1.7	NS
Irradiance	1	0.1529	0.68	NS
Residual	136	0.2263		

DISCUSSION

From earlier work it was known that *D. odora* could be rooted to 100% in culture. Also clear was that subsequent attempts to produce the crop (Table 1) showed widely different rooting responses to the same chemical recipe. Some conditions provided to the cultures had caused a reduction in rooting response.

After human error had been ruled out as a major cause of variable response, first darkness and then general conditions within the growth room, were examined.

General environmental conditions analysed in Tables 2 to 4 give good evidence of the role of environment in rooting. The analyses (summarised in Table 5) clearly show that high night temperatures account for a significant proportion of variation in rooting response.

Table 5. A summary of the results showing the components of the environment that influenced the rooting of *Daphne odora* cuttings.

Effect	Environmental Factor (Cause)		
	Day Temp.	Night Temp.	Irradiance
Start time (T10)	/	//	X
Rate of rooting	X	X	X
Final rooting Percentage	X	//	/

This table shows the factors of the environment and areas of influence on rooting. X = no effect; / = a significant effect; // = a major effect.

Irradiance was also shown to influence the final rooting response. From the analysis in Table 3 it is apparent that darkness reduces rooting and that high night temperatures do likewise (Table 3). Light is required for successful rooting and, as irradiance increases, so also does rooting percentage (Table 3). Higher temperatures were shown in Table 2 to reduce the time to achieve 10% rooting.

The importance of these results, which are specifically relevant only to *D. odora,* is in the implication of how relatively small changes in laboratory conditions combine to influence the success of the system. Similar work to examine shoot multiplication or quality might prove to be as revealing. The combined effect of growth environment could seriously upset the efficiency of production. The same is likely to be true for conventional propagators, more so because the diversity of variable environment is so much greater.

There are many reports in the literature in which some environmental influence is described. Dark treatment before and during rooting has been reported to influence rooting in a number of species, both in conventional propagation systems (1, 4, 5, 8) and in *in vitro* systems (2, 7, 9, 10). Most of the publications report improved rooting due to darkness but Rowell (8) and Norton and Boe (7) also reported species which either had no preferential response due to darkness or which showed inhibition of rooting in the dark.

One advantage of research into rooting using *in vitro* systems is that a reasonably uniform group of one clone may be exposed equally to a manipulated environment. Zimmerman (10) increased the temperature during dark treatment whilst attempting to root

Malus and improved the rooting percentage as a result. It may be that some species respond to auxin differently in light and dark. There may be two systems which do not lead to the same result. Plants whose rooting is promoted by darkness might reasonably be expected to do better at higher temperatures, the response to auxin perhaps being temperature dependent within certain limits. Plants whose rooting response is not favoured by darkness, such as *Cotinus coggyria* (8), *Chaenomeles japonica* (7) and *D. odora* might be expected to show greater inhibition to rooting by increasing night temperature and might also be more effectively propagated in 24 hour days with supplementary lighting.

Although the results indicate that *D. odora* has rooting requirements for low night temperature and high irradiance, it is likely that these two factors are part of the environmental conditions required to cause the preferred response to auxin which, if tested, might be best provided for by 24 hour days.

Within a system that is sensitive to so many potential causes of variation the interpretation of results is hazardous. The analysis here shows that within the conditions tested, night temperature and irradiance influence rooting. A basis must be established which provides constant conditions for two of the variables and allows the proper study of the third. High quality growth rooms which can provide these conditions and maintain stable conditions might also allow research into light quality, and gaseous phase influences on plant growth.

SIGNIFICANCE TO THE NURSERY INDUSTRY

Understanding the contributing factors that control rooting in response to auxin is very important, particularly to micropropagators, but also to conventional plant producers. It is only really cost effective to produce a crop when, out of 100 cuttings taken upwards of 95 root and grow away. Equally important is that all 95 out of 100 cuttings should root as nearly simultaneously as possible so that resultant uniformity leads to a reduction in the labour costs required for grading and other maintenance work, and thus the cost of production is reduced. For all producers the time spent by a crop in propagation areas must be as short and effective as possible, providing heat and light only when required.

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CONTAINER COMPOST pH AND ITS EFFECT ON PLANT GROWTH

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An experimental trial was set up using seven cultivars, each in a different genus. One was an Ericaceous plant. Each of the cultivars was potted into four composts which had varying amounts of dolomitic limestone added to them, except the Ericaceous plants which were potted into only three composts, and with the addition of dolomitic limestone not being at such great extremes.

From the six cultivars used in the trial, quite remarkable differences in growth rates appeared due to varying the amount of dolomitic limestone added to the compost. With this indicating that the compost's pH is critical in obtaining maximum plant growth, pH control can also be used for restricting growth.

With the one Ericaceous cultivar, no difference in growth rates were noticeable, as the addition of dolomitic limestone to the three trial composts was not at great enough extremes to appreciably alter the pH.

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CONTAINER COMPOST pH AND ITS EFFECT ON PLANT GROWTH

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An experimental trial was set up using seven cultivars, each in a different genus. One was an Ericaceous plant. Each of the cultivars was potted into four composts which had varying amounts of dolomitic limestone added to them, except the Ericaceous plants which were potted into only three composts, and with the addition of dolomitic limestone not being at such great extremes.

From the six cultivars used in the trial, quite remarkable differences in growth rates appeared due to varying the amount of dolomitic limestone added to the compost. With this indicating that the compost's pH is critical in obtaining maximum plant growth, pH control can also be used for restricting growth.

With the one Ericaceous cultivar, no difference in growth rates were noticeable, as the addition of dolomitic limestone to the three trial composts was not at great enough extremes to appreciably alter the pH.

The seven cultivars that were used were:

Viburnum tinus 'Eve Price'
Berberis thunbergii 'Atropurpurea Nana'
Ilex aquifolium 'Argenteo-marginata'
Cytisus × *praecox* 'Allgold'
Cistus 'Silver Pink'
Euonymus fortunei 'Emerald Gaiety'
Rhododendron 'Scarlet Wonder' (Ericaceous plant)

Two hundred plants of each cultivar were used except for Berberis thunbergii 'Atropurpurea Nana' where 400 were used, as half were grown under protection of a polytunnel. Only 150 *Rhododendron* 'Scarlet Wonder' plants were used as these were potted into only three trial composts.

The plants were potted on 30 and 31 March, 1985 into 3 litre pots, each of which was colour coded with a coloured dot to relate to the rate of dolomitic limestone in each compost. The compost mix consisted of:

300 litres of Vapo peat
20% of 5mm grit
3 lb of Ficote 140-day 16:10:10
3 oz Fritted trace elements
1 lb Aldrin dust
Dolomitic limestone at 225g (8 oz); 450g (1 lb); 675g (1 lb 8 oz); 900g (2 lb); and for the rhododendron 6 oz, 8 oz, and 10 oz.

Fifty plants of each cultivar were potted into each compost mix. The potting was followed by the standing down where the plants were placed in such a pattern as to give all plants a fair trial and prevent one compost from being in a drier or more exposed position than the others.

Once the plants had all been potted and placed in position, they were left to grow as in a typical situation, except that they were not treated with herbicides, as these would affect the pH of the compost.

The plants were left to grow on in their situation and were monitored at monthly intervals from potting. Recording of pH readings of the compost and also visual differences in growth were taken. The plants growing outside were monitored for a twelve month period as were those under protection but for 7 months (from March, 1985 to October, 1985).

The results of the monthly monitored pH levels are shown in Table 1. The results of the plants' performance are:

Viburnum tinus 'Eve Price'. The best plants were achieved from the liners growing in the 1 lb, 8 oz (675g) of dolomitic limestone compost mix, forming evenly dense plants with good flower bud initiation.

Berberis thunbergii 'Atropurpurea Nana'. The best plants were

Table 1. Results of monthly monitored pH

Rate of added dolomitic lime	1985 MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	1986 JAN	FEB
							Outside					
8 oz	3.8	4.3	4.2	4.0	4.2	4.2	4.6	4.8	4.6	4.8	5.0	4.9
1 lb	4.3	5.0	5.0	4.4	5.0	5.2	4.8	5.0	5.0	5.4	5.8	5.6
1 lb 8 oz	5.0	5.5	5.5	5.1	5.4	6.2	5.4	6.2	5.4	5.9	6.4	6.2
2 lb	5.5	6.1	6.0	5.5	5.8	6.6	6.4	6.1	6.5	6.0	6.6	6.7
							Under Protection					
8 oz	3.8	4.3	4.1	3.9	4.2	4.6	4.6	4.7	—	—	—	—
1 lb	4.3	5.0	5.0	5.0	5.1	5.6	5.2	6.0	—	—	—	—
1 lb 8 oz	5.0	5.6	5.4	5.4	5.5	6.4	5.7	5.8	—	—	—	—
2 lb	5.5	6.5	6.2	5.8	6.0	6.6	6.5	5.9	—	—	—	—
							Ericaceous Plant					
6 oz	3.9	4.1	4.0	4.2	4.2	4.2	4.1	4.1	4.6	4.5	4.7	4.8
8 oz	4.1	4.2	3.9	4.4	4.5	4.5	4.4	4.1	4.8	4.6	4.9	4.8
10 oz	3.9	4.3	4.2	4.5	4.7	4.8	4.6	4.1	4.9	4.9	5.0	4.9

achieved from the liners growing in the 1 lb (450g) dolomitic limestone compost mix and also the same for those under protection, but better plants developed all round.

Ilex aquifolium 'Argenteo-marginata'. The best plants were achieved from the liners growing in the 1 lb (450g) dolomitic lime compost mix, producing an extra flush of growth.

Cytisus × *praecox* 'Allgold'. Maximum plant growth was achieved with the 1 lb (450g), but the 8 oz (225g) compost produced compact plants with better flower bud development and early flowering.

Cistus 'Silver Pink'. The amount of lime in the compost did not seem to make any dramatic differences with the 1 lb (450g) compost, producing a slightly larger plant.

Euonymus fortunei 'Emerald Gaiety'. Poor growth was obtained from the 8 oz (225g) compost, with the 1 lb (450g), 1 lb 8 oz (675g), and 2 lb (900g) producing acceptable plants showing no differences.

Rhododendron 'Scarlet Wonder'. The variations in the amount of lime added to the three composts for the rhododendrons, were not at great enough extremes to show any variation in plant growth.

From the experimental trials it is indicated that plant growth can be promoted or reduced according to the amount of lime used. The pH of the compost can be maintained to an optimum for the required plant growth by nitric acid injection into irrigation water.

PRODUCTION FIGURES FOR MICROPROPAGATED HARDY NURSERY STOCK IN 1986

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Based on the results of a questionnaire sent to 42 commercial laboratories and scientific institutions (Table 1), an attempt is made to show the increasing use of micropropagated material in the hardy nursery stock industry. Twenty-five replies were received; the response from the commercial companies was poor whereas, in general, the scientific institutions gave a good response. In a number of cases, scientific staff went to considerable effort by contacting numerous firms so as to gain as accurate a picture as possible. Furthermore, direct personal contacts made at conferences on micropropagation, plus numerous telephone calls helped to increase the accuracy of the figures presented. However, it must be emphasized that the figures can only be seen as estimates as there is no method of accurately checking them. So far there are no reliable official figures and it is likely that some figures are counted twice as, for example, when a company imports micropropagated plants and sells them as their own product. Few commercial companies are likely to admit that they cannot produce certain lines. It is also possible that some plants are being propagated conventionally from micropropagated plants and then being sold as such. These points should help to explain the discrepancy in some of the figures. It is interesting to speculate how many of the plants produced reach saleable size.

Table 1. Estimated number of plants produced through micropropagation in:

	1980	1982	1984	1985	1986
1. *Rhododendron* (excl. *R. simsii* and the Indian Hybrid Azaleas)					
2. Azalea (deciduous)					
3. Other ericaceous plants (Please specify if possible)					
4. Rootstocks:					
Malus					
Prunus					
Other					
5. Roses, by cultivar					
6. Forest trees (Please specify if possible)					
7. *Other hardy ornamental plants* (Please specify if possible)					

The production of *Rhododendron* through micropropagation has increased very rapidly over the past six years. The figures presented for this crop show that this propagation method is likely

to become even more important for this species in the coming years. In Table 2 it can be seen that the development in the USA has been most rapid. Published figures (Jones, 1985) show that about 8 million rhododendron plants are now (1986) being grown *in vitro* in the USA. Other well informed specialists doubt that this number is correct and estimate that about 4 million would be a more accurate figure. Positive support from the scientific institutions as well as incentives from the government has led to a rapid expansion in *Rhododendron* production in Belgium. About 600,000 were produced there in 1986. There is rapid expansion also in Great Britain, due mainly to the efforts of one or two companies. Production in Britain is likely to have surpassed Belgium. Interesting is the almost total absence of activity in The Netherlands. Large quantities of Belgian-produced plants are being grown on to saleable liners in Boskoop.

Table 2. Estimated number (,000) of evergreen rhododendrons (excl. *R. simsii* and the Indian Hybrid Azaleas) produced through micropropagation in different countries (1980–86).

	USA	Belgium	G.B.	France	Can.	CH	Poland	Neth.
1980	250	—	—	3	—	—	—	—
1982	1500	60	—	6	—	—	—	—
1984	3000	250	100	47	3	—	—	—
1985	3000–5000	500	250	51	10	—	5	1–5
1986	4000–8000	600	500–750	?	20	2	10	1–5

Table 3. Estimated number (,000) of deciduous azaleas produced through micropropagation in different countries (1980–86).

	USA	Can.	G.B.	Poland
1980	250	—	—	—
1982	500	—	—	—
1984	800–1000	1	—	—
1985	1000–1500	5	1	—
1986	2500+	20	1	1

With the exception of the USA, only limited quantities of deciduous azaleas are being produced *in vitro* (Table 3).

Table 4 shows that the production of *Vaccinium* is increasing only gradually in the USA, where about 500,000 plants are being produced each year through micropropagation. In Australia production is likely to have dropped dramatically from a peak of 330,000 in 1984 to only 90,000 in 1986. Possible explanations for this situation could be reduced cropping in the early stages due to an extended juvenile stage, or an increase in the mutation rate. The expansion in area under *Vaccinium* culture may not have developed as rapidly as anticipated.

Table 4. Estimated number (,000) of *Vaccinium* Plants being produced through micropropagation in different countries (1982–86).

	USA	Aust.	Can.	Belgium	Poland
1982	100	—	2	—	—
1984	150–250	330	?	—	—
1985	200–400	320	?	10	—
1986	200–500	90	10	?	10

The production of *Kalmia latifolia* by conventional means is very difficult. Micropropagation has led to a rapid increase in the number of plants being sold. The number will increase much more rapidly when the initial growing-on problems have been solved. Some cultivars take a long time to get growing. Largest production is in the USA with approximately 200,000 in 1986 (Table 5). Production is increasing in Great Britain, but many plants are still being imported from North America. *Kalmia* is one of the few shrubs being produced through micropropagation in reasonable numbers in The Netherlands (50,000).

Table 5. Estimated number (,000) of *Kalmia latifolia* being produced through micropropagation in different countries (1982–86).

	USA	G.B.	Neth.
1982	50	—	—
1984	100–150	—	?
1985	150–200	50	30–50
1986	200+	?	50+

Table 6 shows that Italy is leading the field in the production of *Malus* and *Prunus*, 250,000 and 3,000,000 were produced, respectively, in 1986. A large drop in *Malus* rootstock propagation is explained by the lack of sales for M 27 and the non-suitability of the plants for budding due to their juvenility. They seem to be most suitable for stool bed planting. Up to 300,000 apple rootstocks are being produced in Spain. This figure may reflect Spain's joining the European Economic Community where it will enjoy full access to the Community's market. There is likely to be a rapid increase in production of *Prunus* rootstocks in Greece where numerous new commercial laboratories are being set up.

France is the largest producer of roses through micropropagation (Table 7), about 3,000,000 being produced annually. At least 50% are used in cut flower production because they are more vigorous than conventionally propagated plants and give a higher yield. Great Britain is the second most important producer of roses, where production has been about 1,000,000 in both 1985 and 1986. It is likely that production will increase next year after the reorganiza-

tion of one of the major producers. It would appear that the production of roses *in vitro* is now getting underway in the USA where only 500,000 are now being produced. Poland is increasing production rapidly, due mainly to the appearance of numerous private commercial laboratories. Most plants are being produced for cut flower producers.

The production of forest trees through micropropagation is not yet very significant (Table 8). In France and Belgium *Prunus avium* is now being produced in limited quantities. In France selected clones suitable for the different regions are available and are supposed to be particularly suitable for cherry wood production. Approximately 200,000 poplars are being produced in West Germany by one company. Poplars are the only hardy woody plants being propagated through micropropagation in such quantity in that country. Production of poplars through micropropagation seems to have ceased in The Netherlands where approximately 100,000 were produced in 1984. It appears they were propagated for a German company which is now getting its supplies in Germany.

Numerous other plants are being produced commercially through micropropagation. The quantities are in general quite small and in a few cases represent single orders. In the USA the following plants are being grown in vitro:

Acer (especially *Acer rubrum* cultivars)	200,000+
Nandina	200,000+
Malus (crabapples)	150,000+
Syringa	200,000+
Paradox walnut rootstocks	50,000

Quantities of 25,000 or less are being produced of the following species: *Amelanchier, Betula, Clematis, Corylopsis, Cotinus, Daphne, Hypericum,* and *Magnolia*.

Although the figures presented here account for only a fraction of the plants being produced in nurseries, one must not forget that this propagation method has only been used commercially for about ten years. Given the intense interest in this method and the investment in laboratories around the world, one must come to the conclusion that in 1986 development is only in the early stages.

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Table 6. Estimated number (,000) of *Malus* and Prunus rootstocks being produced through micropropagation in different countries (1982–86).

a) *Malus*

	Italy	Spain	Belgium	USA
1982	500	—	10	—
1984	500	—	10	2–5
1985	400	?	10	2–5
1986	250	300	?	2–5

b) *Prunus*

	Italy	*Belg.*	*Greece*	*Aust.*
1982	*1500*	*10*	*10*	—
1984	*3000*	*00*	*20*	—
1985	*3000*	*250*	*30*	*5*
1986	*3000*	*?*	*50*	*25*

Table 7. Estimated number (,000) of roses produced through micropropagation in different countries (1980–86).

	France	G.B.	USA	Aust.	Poland
1980	135	—	—	—	—
1982	1200	—	—	—	—
1984	2500	300	?	10	—
1985	*2800*	*1000*	100–175	*11*	*50*
1986	?	1000+	500	20	150

Table 8. Estimated number (,000) of forest trees produced through micropropagation *in different countries (1982–86).*

	France	Germany	Belgium	Neth.
1982	4	—	—	—
1984	30	?	3	50–100
1985	100–150	100–200	20	?
1986	150–160	100–200	?	—

MICROPROPAGATION OF CATAWBA HYBRID RHODODENDRONS, 'NOVA ZEMBLA', 'CYNTHIA', AND 'PINK PEARL'

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Abstract. The *in vitro* response of floret explants of three Catawba hybrid rhododendron cultivars—'Nova Zembla', 'Cynthia' and 'Pink Pearl' to varying indoleacetic acid (IAA) and (Δ^2 Insopentenyl)—adenine (2iP) levels is described.

Although the explants of the three cultivars under investigation differed in their exogenous growth regulator requirements, it was found that relatively high auxin (2.0 to 4.0 mg l^{-1}) and cytokinin (10.0 to 15.0 mg l^{-1}) concentrations were necessary to induce adventitious growth.

Caulogenesis of both 'Nova Zembla' and 'Cynthia' cultures was maximised only if IAA was omitted from the medium. Both cultivars had an absolute requirement for 2iP; the former within the range 5.0 to 15.0 mg l^{-1}: the latter, 5.0 mg l^{-1}. Maximum propagule development occurred at 1.6 mg l^{-1} for micropropagules derived from shoot tip explants used as the test material.

In vitro culture has proved to be an effective method for the rapid propagation of many plant genera, particularly herbaceous genotyes (12, 13). Within the past decade, considerable research efforts have been directed toward development of tissue culture systems for woody plant species (1, 17, 18). Rhododendron is one such species which responds to tissue culture (2, 3, 15). However, some factors require further elucidation and refinement. For example, the concentration of exogenously supplied auxin and cytokinin compounds to the culture medium at any specific stage.

There are conflicting reports regarding the recommended concentration of both IAA and 2iP which should be used in rhododendron tissue culture media. Currently, this is arbitrary, non-specific and often depends upon the investigator. Concentrations used have ranged between zero and 6.0 mg l^{-1} for IAA Anderson (4) and 1.6 and 15.0 mg l^{-1} for 2iP (4, 5, 6, 7, 9, 14).

This research was initiated to examine the effects of varying IAA and 2iP concentrations on floret explant material excised from three rhododendron cultivars.

MATERIALS AND METHODS

Propagation material of the three cultivars was harvested from 3 to 5 year old mother plants kindly supplied by Bord Na Mona shrub nursery, Lullymore, County Kildare. The florets were washed in 1% v/v detergent for 20 min. followed by immersion and agitation for 30 min. in 0.5% v/v sodium hypochlorite solution containing 0.1% v/v Tween 20. They were rinsed three times with sterile distilled water.

Papery coverings which surrounded the florets were aseptically removed using a forceps and scalpel; each was dissected leaving the maximum amount of intact pedicel tissue and placed within a 50 mm sterilin petri dish containing a nutrient agar medium. Where adventitious tissue clusters were used as the innoculum, they were simply sub-cultured onto a fresh medium. Where micropropagules were used as innoculum, four nodal shoots excised below the 1st and 5th internodes were singularly placed horizontally on the surface of the culture medium within 100 ml sterilin specimen containers. Ten replications were used in each treatment. The basal medium composition was that of Anderson's 1984 revised rhododendron one. The pH was adjusted to 5.0 ± 0.1 with 1 m KOH or HCl prior to the addition of agar and was autoclaved at 0.7 kg cm^{-2} and 110°C for 20 min. The medium was allowed to cool to 37°C, thereupon the thermolabile substances were filter sterilized using Miller-HA 0.45 μM filters attached to a 50 ml Millipore syringe. The medium was dispensed (20 ml) into the respective culture vessels using a 10 ml BD Cornwall automatic dispensing apparatus.

Experiments with a range of IAA and 2iP concentrations (0.0, 2.0, 4.0 mg l^{-1} and 5.0, 10.0, 15.0 and 20.0 mg l^{-1}), respectively, were carried out for all experiments except where nodal shoots of 'Pink Pearl' were used. In this instance 2iP was supplied at 0.0, 1.6, 2.5, 5.0, 10.0, 15.0, and 20.0 mg l^{-1}. The cultures were incubated in a growth chamber at a temperature of 25°C and a photon flux density of 30 ± 10 UE m^2 sec^{-1}. A 16 hour photoperiod was maintained using Phillips warm white florescent tubes.

The results were evaluated by measuring the size of the induced adventitious tissue growth after 8 weeks growth (Tables 1, 2, 3); by counting the total number, and number of usable shoots, at 12 and 16 weeks (Tables 4, 5, 6, 7, 8). The data was statistically analysed using the factorial analysis of variance and Duncan's Multiple Range Test

RESULTS

The addition of auxin and cytokinin compounds to the culture medium had a highly significant effect on adventitious growth and development of floret explants for the three cultivars investigated.

'Nova Zembla' explants established rapidly and produced adventitious growth clusters measuring 913 and 1021 mm^3, when auxin was added at 2.0 and 4.0 mg l^{-1} respectively (Table 1). These values were not significantly different. When auxin was omitted from the medium, adventitious tissue growth was significantly retarded (Table 1).

Table 1. Effect of auxin and cytokinin concentration on adventitious growth development (mm^3) from floret explants of *Rhododendron* 'Nova Zembla'

Auxin mg l^{-1}	Cytokinin mg l^{-1}				
	5	10	15	20	Weighted mean
0	100	545	392	—	432 b
2	1121	—	692	844	913 a
4	1063	1232	905	802	1021 a
Mean	1028 a	971 a	673 a	814 a	

Means followed by the same letter are not significantly different at the 5% level.

Comparing cytokinin concentrations for the above cultivar, there was a general decrease in adventitious tissue development with increasing cytokinin concentration (Table 1). Maximum growth occurred at 5.0 mg l^{-1}, whilst the minimum occurred at 15.0 mg l^{-1} 2iP. However, these differences were not significant.

Although no significant interaction occurred between the relative auxin and cytokinin concentration, development was maximised between 2.0 and 4.0 and 5.0 and 10.0 mg l^{-1} IAA and 2iP, respectively (Table 1).

'Cynthia' floret explants established and grew rapidly in culture. They grew slowly in the absence of auxin and rapidly when it was added to the culture medium at 2.0 mg l^{-1}. This difference was highly significant. (Table 2).

Explant growth rate was intermediate at 4.0 mg l^{-1} also being significantly better than when auxin was omitted (Table 2).

Increasing cytokinin concentrations tended to increase adventitious growth, and generated adventitious tissue clusters measuring between 449mm^3 and 752mm^2 at 5.0 and 50.0 mg l^{-1}, respectively (Table 2). However, there was no significant difference between any of the concentrations used.

Table 2. Effect of auxin and cytokinin concentration on adventitious growth development (mm^3) from floret explants of *Rhododendron* 'Cynthia'

Auxin mg l^{-1}	Cytokinin mg l^{-1}				
	5	10	15	20	Weighted mean
0	195	355	308	—	229 b
2	830	1385	747	915	918 a
4	—	339	1206	838	748 a
Mean	449 a	630 a	751 a	752 a	

Means followed by the same letter are not significantly different at the 5% level.

A significant interaction occurred between the two growth regulators for promotion of floret growth, at 2.0 and 10.0 mg l^{-1} IAA and 2iP, respectively (Table 2).

'Pink Pearl' explants grew best at 2.0 mg l^{-1} IAA; at 4.0 mg l^{-1}

IAA growth was significantly retarded whilst at 0.0 mg l^{-1} IAA, no growth occurred. (Table 3).

In common with 'Cynthia' floret explant growth, those of 'Pink Pearl' also grew in response to increased cytokinin concentrations up to 15.0 mg l^{-1} 2iP (Table 3). Although growth was greatest at this concentration, it was not significantly different from any of the others under test. No significant interaction occurred between auxin and cytokinin for the given parameter (Table 3). However, the results indicate an optimum IAA and 2iP combination of 2.0 and 10.0 to 15.0 mg l^{-1}, respectively, for adventitious tissue development of floret explants of this cultivar (Table 3).

Table 3. Effect of auxin and cytokinin on adventitious growth development (mm^3) from floret explants of *Rhododendron* 'Pink Pearl'.

	Cytokinin mg l^{-1}				
Auxin mg l^{-1}	5	10	15	20	Weighted mean
0	—	0	8	0	3 c
2	93	526	735	348	428 a
4	—	35	173	79	120 b
Mean	128 a	206 a	292 a	222 a	

Means followed by the same letter are not significantly different at the 5% level.

The auxin and cytokinin concentrations used in the shoot induction medium had a highly significant effect on caulogenesis of 'Nova Zembla' and 'Cynthia' cultures only. For instance, propagule induction in 'Nova Zembla' cultures was greatest when no auxin and least when 4.0 mg l^{-1} IAA was added to the medium. The greatest decrease (49%) occurred between 0.0 and 2.0 mg l^{-1} IAA (Table 4).

Table 4. Effect of auxin and cytokinin concentration on shoot production from *in vitro* derived masses of adventitious buds of *Rhododendron* 'Nova Zembla' after 16 weeks in culture.

	Cytokinin mg l^{-1}				
Auxin mg l^{-1}	5	10	15	20	Weighted mean
0	58	38	54	44	49 a
2	11	15	26	45	25 b
4	6	8	23	43	21 b
Mean	24 b	23 b	38 a	44 a	

Means followed by the same letter are not significantly different at the 5% level.

The level of cytokinin in the medium also significantly influenced caulogenesis of 'Nova Zembla' cultures. In direct contrast with adventitious tissue development, caulogenesis increased with increasing 2iP concentration, and was maximised at 20.0 mg l^{-1} (Table 4). However, at this level it was not significantly different

from that at 15.0 mg l^{-1}. At 5.0 and 10.0 mg l^{-1} caulogenesis was significantly inhibited (Table 4). A significant interaction between auxin and cytokinin also occurred. Caulogenic growth was greatest at 0.0 and 5.0 mg l^{-1} IAA and 2iP respectively (Table 4).

Further analysis showed that the number of usable 'Nova Zembla' propagules (>10mm) was also significantly influenced by the levels of the respective growth regulators in the medium. To this end the absence of auxin was critical (Table 5). In fact the number of usable shoots dropped 340% compared with production when IAA was added at 2.0 mg l^{-1} (Table 5). In contrast the cytokinin concentration was not critical, and no significant difference occurred irrespective of the concentration used (Table 5). However, high 2iP levels (15.0 mg l^{-1}) favoured the development of such propagules (Table 5).

Table 5. Effect of auxin and cytokinin concentration on the number of usable shoots produced from *in vitro* derived masses of adventitious buds of *Rhododendron* 'Nova Zembla' after 16 weeks in culture.

	Cytokinin mg l^{-1}				
Auxin mg l^{-1}	5	10	15	20	Weighted mean
0	19	18	23	9	17 a
2	4	0	2	5	5 b
4	1	—	2	7	4 b
Mean	8 a	8 a	12 a	9 a	

Means followed by the same letter are not significantly different at the 5% level.

Although an auxin/cytokinin interaction occurred, it was not highly significant. The maximum number of usable propagules occurred at 0.0 and 15.0 mg l^{-1} IAA and 2iP respectively.

In common with the cultivar, 'Nova Zembla', 'Cynthia' cultures also produced more propagules when auxin was omitted from the medium. Growth decreased significantly; 34% when IAA was increased from 0.0 to 2.0 mg l^{-1} and 65% when it was increased from 0.0 to 4.0 mg l^{-1}, respectively (Table 6). Similarly there was also a significant decrease when it was increased from 2.0 to 4.0 mg l^{-1}.

The concentration of cytokinin in the culture medium also significantly influenced caulogenesis of 'Cynthia' cultures. It was best at 15.0 and least at 20.0 mg l^{-1} 2iP, respectively (Table 6).

Although no significant interaction occurred between the two, 0.0 and 5.0–15.0 mg l^{-1} IAA and 2iP, respectively, induced the maximum number of propagules.

Further analysis disclosed that the numbers of usable propagules (>10mm) harvested from 'Cynthia' cultures varied in accordance with the relative auxin and cytokinin concentration used in the culture medium (Table 7).

Table 6. Effect of auxin and cytokinin concentration on shoot production from *in vitro* derived masses of adventitious buds of *Rhododendron* 'Cynthia' after 16 weeks in culture.

Auxin mg l^{-1}	Cytokinin mg l^{-1}				
	5	10	15	20	Weighted mean
0	52	46	51	42	47 a
2	19	24	46	22	31 b
4	14	25	17	7	16 c
Mean	26 b	35 a	39 a	25 b	

Means followed by the same letter are not significantly different at the 5% level.

Table 7. Effect of auxin and cytokinin concentration on the number of usable shoots produced from *in vitro* derived masses of adventitious buds of *Rhododendron* 'Cynthia' after 16 weeks in culture.

Auxin mg l^{-1}	Cytokinin mg l^{-1}				
	5	10	15	20	Weighted mean
0	19	11	16	7	12 a
2	9	8	18	7	12 a
4	2	3	1	2	2 b
Mean	9 ab	8 ab	13 a	6 b	

Means followed by the same letter are not significantly different at the 5% level.

At low auxin concentrations (0.0 and 2.0 mg l^{-1} IAA) no difference occurred in the number of such propagules generated. However, at 4.0 mg l^{-1} their number decreased six fold (Table 7).

There was no significant difference in the number obtained at 2iP concentrations between 5.0 and 15.0 mg l^{-1}, respectively. However, at the 20.0 mg l^{-1} there was a significant decrease (Table 7).

No significant interaction between auxin and cytokinin occurred for this parameter, neither was there little difference in the number of usable propagules produced at 0.0 and 5.0 mg l^{-1} and 2.0 and 15.0 mg l^{-1} IAA and 2iP respectively. Adventitious tissue clusters of 'Pink Pearl' remained recalcitrant and failed to differentiate sufficient numbers of usable propagules derived from florets. However, when micropropagules derived from shoot tip cultures of 'Pink Pearl' were tested under seven 2iP concentrations alone, its addition to the culture medium had a marked influence on their subsequent growth and caulogenic rates. The highest number of propagules occurred within the range 1.6 to 5.0 mg l^{-1}, but was greatest at the former (Table 8). The lowest rates occurred at concentrations in excess of 10.0 mg l^{-1} (Table 8).

Table 8. The effect of seven concentrations of 2iP on caulogenesis and shoot size of *Rhododendron* 'Pink Pearl' propagules.

Treatment	Mean shoot No.	Mean shoot No. >10mm	Mean shoot No. <10mm
2iP (mg l^{-1})			
0	0.43[a]	0.16[a]	0.27[a]
1.6	3.16[b]	1.90[b]	1.26[b]
2.5	2.26[bc]	1.02[cd]	1.60[b]
5.0	2.75[bc]	1.55[bc]	1.20[b]
10.0	2.23[cd]	0.85[de]	1.38[b]
15.0	1.73[d]	0.45[de]	1.28[b]
20.0	1.28[d]	0.30[e]	1.58[b]

Means followed by the same letter are not significantly different at the 5% level.

The maximum number of usable shoots (>10mm) occurred at 1.6 and 5.0 mg l^{-1} whilst the minimum number occurred at higher levels: 10.0 to 20.0 mg l^{-1}, respectively. These differences were highly significant (Table 8). In contrast there was no difference in the number of non-utilizable shoots (<10mm) produced at all levels, except when 2iP was omitted from the medium.

DISCUSSION

The results demonstrate the variability between floret explants of rhododendron cultivars in response to the inclusion of IAA and 2iP at varying ratios in the culture medium. In general 'Nova Zembla' was the most responsive irrespective of the growth regulator concentrations used; 'Pink Pearl' was the least and, in some instances, failed to regenerate adventitious tissue, especially when IAA was omitted from the medium.

In accord with the findings of Anderson (1980) these results demonstrate an absolute requirement for IAA in the explant medium to promote explant development and growth. Similarly, with respect to the 2iP concentration used, these results compare with those of Strode *et al* (16), Hannapel *et al* (9), Anderson (3), and Ettinger and Preece (7), insofar as high 2iP concentrations (10.0 to 15.0 mg l^{-1}) promoted moss-like adventitious growth, a necessary step in the evolution of micropropagules derived from floret explants.

In contrast with the findings of Economou (6), Meyer (11), and Anderson (4), additions of IAA to the sub-culture medium neither enhanced caulogenesis nor improved micropropagule quality. In fact, the cultures lost their requirement for exogenous auxin and grew better at all cytokinin concentrations in its absence. On the contrary, if it were added to the medium, a rapid decline in caulogenic rates occurred at all 2iP concentrations, thus masking any cytokinin activity. This was greatest at 4.0 mg l^{-1} IAA for both 'Nova Zembla' and 'Cynthia'. This phenomenon has not previously

been reported for rhododendron tissue cultures. It is probable that the cultures either accumulated sufficiently high endogenous IAA concentrations or became habituated and autonomously developed auxin biosynthetic pathways during the establishment phase, thus enabling them to grow and develop rapidly when sub-cultured.

The results suggest that, unlike IAA, the 2iP concentration in the sub-culture medium is not critical and may range between 5.0 and 15.0 mg l^{-1}, depending on the cultivar, for material derived from floret explants. However, when 'Pink Pearl' cultures derived from shoot tip explants were sub-cultured, the maximum number of propagules occurred at 1.6 mg l^{-1}. This compares with the findings of McCown and Lloyd (10). It contrasts with the above findings, and also with those of Strode *et al* (16) and Anderson (4) who recommended 1.0 and 5.0 mg l^{-1} IAA and 2iP, respectively. Similarly, it contrasts with those of Fordham *et al* (8), Douglas (5), and Ettinger and Preece (7) who recommended levels as high as 15.0 mg l^{-1}, irrespective of the attendant risk of adventitious tissue induction at such levels.

In the latter experiment IAA was omitted from the medium and its deletion may explain the efficacy of the lower 2iP concentration and conceivably enhance its effectiveness at such low levels.

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PROPAGATION OF *EMBOTHRIUM COCCINEUM*, *CARPENTERIA CALIFORNICA*, AND *FREMONTODENDRON* 'CALIFORNIA GLORY'

NIGEL J. TIMPSON

Hewton Trees and Shrubs

Bere Alston, Yelverton, Devon, PL20 7BW, England

There are often many different ways of propagating a particular plant which will achieve the same result. What is described in this paper are the methods used at Hewton Trees and Shrubs for the propagation of *Embothrium coccineum*, *Fremontodendron* 'California Glory', and *Carpenteria californica*, all of which are often considered to be difficult subjects. All three types of plant are propagated in a similar way so the majority of the paper is devoted to the description of *Embothrium coccineum*, reference being made to any differences in the method for the other plants.

BACKGROUND AND BOTANICAL INFORMATION

Embothrium coccineum, a native of Chile and bordering parts of Argentina from about 37° south to Tierra del Fuego, was first introduced to Great Britain by William Lobb in 1846. In the wild it grows from the coast up to the tree line and as a small bush up to an 8 metre tree; in cultivation it can be even taller.

Plants growing in the United Kingdom are either evergreen or semi-deciduous. There is confusion over nomenclature, but all are synonyms of *Embothrium coccineum*, and all produce a profusion

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of orange-red flowers in May and early June. There is a particularly good-flowering semi-evergreen cultivar known as 'Norquinco' after the west Argentine valley in which the seed was collected.

Carpenteria is a genus of a single species, namely *Carpenteria californica*, which was introduced to this country in about 1880. It is an evergreen shrub which is a native of California and grows to about 4 metres high. The large white flowers with conspicuous yellow anthers are produced in July. There is a vigorous free-flowering form with large flowers known as 'Ladham's Variety'.

Fremontodendron 'California Glory' is a semi-deciduous shrub which originated in California in 1952. It is a very vigorous, free-flowering hybrid raised from seed of *F. californicum* grown in the company of a plant of *F. mexicanum*. Bright yellow flowers are produced in large numbers from May to July.

Embothrium is generally hardy in the south of England, but both *Fremontodendron* 'California Glory' and *Carpenteria californica* will suffer damage in a hard winter unless planted in a protected position. All these plants tend not to be long-lived.

PROPAGATION

Embothrium coccineum is frequently propagated by seed and we use this method. Seed propagation has the advantage that it is very cheap in terms of propagation costs but it is a number of years before the plants produce flowers. Some plants in the United Kingdom will produce viable seed and this should be collected at the end of September or early October. The seed pods, which are 20 to 30 mm long and contain numerous winged seeds, are dried naturally until they open. The seed then has to be cleaned and de-winged in preparation for sowing in March in seed trays. A lime-free compost is used, made up of equal parts of sand and peat, incorporating 0.8 kg/m^3 of single superphosphate and 0.4 kg/m^3 of potassium nitrate. The seed normally germinates very easily and is ready for potting by the middle of May. The seedlings are best handled quite small since they do not tolerate much root disturbance.

Embothrium coccineum forms "lanceolatum" and "longifolium" are rooted from cuttings normally taken in early February. At this point it should be noted that typical *E. coccineum* tends to be more difficult to root than the forms under discussion and that any semi-deciduous cultivar such as 'Norquinco' will not root at this time of year; they are much easier from cuttings taken in July.

Cuttings are taken from the current year's growth, wounded, and stuck in 7 cm pots filled with pure lime-free sand. This sand is a waste product from the China clay industry, and is excellent for propagation. The use of pots reduces root disturbance on potting. A hormone rooting mixture is used consisting of three parts Seradix No. 2 and one part Captan. The pots are placed on a heated bench

under mist, which is manually controlled to prevent excessive wetness. Bottom heat is maintained at around 18°C. During propagation the cuttings are given a liquid feed every 2 to 3 weeks using Phostrogen at the recommended rate.

Fremontodendron 'California Glory' may be propagated from seed but the resulting plants would not be true to name. We propagate this plant and *Carpenteria californica* in exactly the same way as *Embothrium* except that cuttings are taken in October.

POTTING

As already mentioned, potting of *Embothrium* seedlings takes place as soon as they are ready in May. The compost used consists of four parts peat and one part sterilised loam, with the addition of about 10% sharp sand. *Embothrium* plants appear to be very sensitive to fertiliser levels and the only fertiliser used is Phostrogen at a low rate of 0.35 kg/m^3. In addition, Aldrin at a rate of 0.7 kg/m^3 is included in the compost.

After potting the plants are placed in a shaded cold frame where they are kept for the summer. If required they are fed with Phostrogen every three weeks during the growing season.

Embothrium cuttings are normally rooted by about the end of April and are then potted into 9 cm pots using a compost similar to that used for the seedlings but with twice the rate of Phostrogen in the mix. The freshly-potted plants are kept under mist to start with and given a certain amount of bottom heat to encourage root development. The plants will be weaned after 10 to 14 days and after 4 to 5 weeks will be moved to a netting shade tunnel.

Carpenteria californica and *Fremontodendron* 'California Glory' are both potted during May using a lime-free compost incorporating a slow release fertiliser. During the 1986 potting season we successfully used Ficote (14:14:14) 140-day fertiliser at a rate of 1.5 kg/m^3 for *Fremontodendron* and a rate of 1.0 kg/m^3 for *Carpenteria*. If space allows they will be kept under mist in the glasshouse to start with, although they could equally well go straight into a polythene tunnel, where they remain until ready for sale.

PESTS AND DISEASES

Embothrium plants suffer very little from pests and diseases. There can be a problem with tortrix moths and we have occasionally suffered an attack from scale. The main problems with *Carpenteria* and *Fremontodendron* are again tortrix, but also red spider which needs to be identified and treated at an early stage to avoid the plants becoming unsaleable.

AVAILABILITY FOR SALE

Embothrium cuttings establish quickly and become ready for sale as young plants from about the middle of June onwards; seedlings, on the other hand, need most of a growing season to develop sufficient roots. Plants of *Carpenteria* and *Fremontodendron* are also slower and start to become available from July onwards.

RESULTS FOR 1985/86 SEASON

The severe winter weather early in 1985 badly affected our *Fremontodendron* plants, with the result that only about 45% of cuttings taken were actually potted. Not only was the number of cuttings reduced but their quality was poor. Our normal success rate is about 80%.

Carpenteria californica is not an easy plant to root and 65 to 70% is our approximate overall success rate. This year we succeeded with about 55%. It is very difficult to stop the cuttings from rotting off, and therefore vitally important to remove damaged leaves as soon as they appear.

Embothrium seedlings, which were potted this year, have done well. On 15 July 1986 the approximate status of those potted was as follows:

No. seedlings over 8 cm high on 15/7/86	200	(7%)
No. healthy seedlings 3–8 cm high on 15/7/86	1800	(63%)
No. dead or unlikely to make the grade	840	(30%)
No. potted w/e 23/5/86	2840	

With *Embothrium* cuttings we would normally expect around 85% success, but this year the cutting material was excellent and we obtained our best ever results as shown below:

Embothrium coccineum, "lanceolatum" form

Total no. of cuttings taken 6/2/86	1579	
Approximate date rooting began	20/3/86	
Cuttings lost	166	(10.5%)
Potted, 1st potting 3/5/86	1359	(86.1%)
Potted, 2nd potting 18/6/86	54	(3.4%)
Total potted	1413	(89.5%)
Sold or available for sale as liners by 15/7/86	1222	(86.5%)
Not ready for sale 15/7/86	185	(13.1%)
Potted plants lost	6	(0.4%)

Embothrium coccineum, "longifolium" form

Total no. of cuttings taken	1294	
Approximate date rooting began	20/3/86	
Cuttings lost	45	(3.5%)
Potted, 1st potting	1235	(95.4%)
Potted, 2nd potting	14	(1.1%)
Total potted	1249	(96.5%)
Sold or available for sale as liners by 15/7/86	1116	(89.4%)
Not ready for sale 15/7/86	125	(10.0%)
Potted plants lost	8	(0.6%)

CONCLUSIONS

The inconsistent results obtained over a period of years are difficult to explain, but are possibly related to the effects of the previous growing season on the propagation material. What is quite certain is that high quality propagation material is particularly important if good results are to be achieved.

Micropropagation techniques have been successful with all three plants, and it may be that conventional propagation will eventually be redundant. Whether or not the plants produced by micropropagation will grow as well as those from cuttings, or will be produced more economically remains to be seen.

TASMANIA, AND THE PLANTS WE PROPAGATE THERE

HENRY A. VAN DER STAAY

Westland Nurseries
Hobart, Tasmania

Tasmania is the smallest state in the commonwealth of Australia. Our total land area is equivalent to that of the Irish Republic. Most of the state is mountainous with numerous lakes and beautiful scenery. Being an island state and away from any cold landmasses our climate is very moderate. Temperatures in the mid-thirties are rare, while during the winter the temperature seldom drops below freezing.

This means that we can grow a very wide range of plants. Apart from a wide range of native flora, one will find all kinds of European, American, New Zealand and South African plants. All native trees and shrubs are evergreen and many of those flower during the winter months supplying food for many honey-eating birds.

A large proportion of our native plants are eucalypts, which come in all shapes and sizes. Many of them have silvery leaves like *Eucalyptus cordata,* which reduces water loss during a dry period.

In the rain forest areas tree ferns, *Dicksonia antarctica,* are abundant and some of them will grow to 50 feet in height.

Eucalyptus ficifolia (scarlet flowering gum) grows into a small tree and displays a mass of flowers, ranging in color from red to pink or white and is summer-flowering. *Eucalyptus leucoxylon* 'Rosea' is winter-flowering.

Another very large group are the acacias or wattles, as they are called. They vary from medium sized trees to dwarf shrubs and most of them are winter-flowering with a few exceptions.

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A popular New Zealand species is *Metrosideros excelsus*, or N. Z. Christmas tree, which flowers around Christmas (mid-summer) with masses of bright red flowers.

We have numerous shrubs with bottle brush type flowers, such as *Banksia marginata* and *Banksia collina*, which form small trees and are often found in exposed positions.

A lot of breeding work takes place with the *Grevillea* species, which come in numerous shapes and sizes. The tallest growing one is *Grevillea robusta*, although being a subtropical tree it grows very well in Tasmania. Some hybrid ones are *Grevillea* 'Poorinda Peter', *G.* 'Ivanhoe', *G. juniperina*, and *G.* Poorinda Queen'. All these and dozens more are popular with the home gardeners as most of them flower all year and attract honey eaters to the garden.

Another group with bottle-brush-type flowers are the callistemons; this is also a genus popular with hybridizers. A few examples are *Callistemon citrinus*, *C. viminalis* and a special West Australian selection called *C.* 'Kings Park Special'.

An import from California is *Lavatera assurgentiflora*, which is extremely fast growing and flowers for a very long time.

Anigozanthus, or kangaroo paw, is a typical Australian native and a lot of breeding is going on with some excellent results.

An interesting little creeper is *Sollya heterophylla*, which also comes in a pink and a white form.

Baeckea densifolia is a low, spreading shrub with masses of white flowers.

Crowea exalata is a beautiful shrub with masses of pink flowers.

Tibouchina urvilleana 'Edwardsi' [syn. *Lasiandra* 'Edwardsi'], a native of Brazil, is an easily grown, very long flowering shrub.

The prostantheras, or mint bush, include a number of aromatic shrubs, which are very free-flowering, with mauve or pale blue flowers.

Cassia is a large genus of mainly tropical species. But some, like *Cassia corymbosa*, grow well under our conditions and produce masses of bright yellow flowers.

Clethra arborea, or lily-of-the-valley tree, grows into a small tree and produces lily-of-the-valley-like bunches of flowers.

Convulvulus cneorum, a native of south Europe is a useful rock-garden species.

Myoporum floribundum has an unusual growth habit and makes an interesting garden specimen.

An important group is that of the Boronia family. *Boronia heterophylla* or red boronia is well known and easily grown. *Boronia megastigma*, or brown boronia, is the most widely grown boronia as a garden shrub for acid soils and as a cut flower. The flowers are extremely heavily perfumed and much sought after. It is probably worth trying to grow this plant as a house plant in your

country; if you succeed in getting it to flower, sales are guaranteed.

It can be grown from seed or cuttings, sown on top of peat-moss. The seedlings are usually a bit variable in growth habit and we mainly use cuttings of selected plants. Boronia plants do best in an acid soil and should be grown in full sunlight outside during the summer months and brought in under frost free, but light conditions during the winter. Flowering is in early spring. Boronia will stand a few degrees of frost without ill effects.

Some *Leptospermum* cultivars ("tea-trees" as we call them) could also offer some possibilities as a house plant. Some larger growing plants are *Leptospermum scoparium, L.* 'Coconut Ice', *L. scoparium* 'Horizontalis', and one which could be considered for use as a houseplant is *L. scoparium* 'Nanum', which only grows to about 12 in. tall; it usually flowers in winter with masses of red flowers. All of the tea-trees are propagated from cuttings.

The last ones I would like to mention are the New Zealander *Hebe* 'Wairiki' and *H. buxifolia*. Both will stand a few degrees of frost and, if grown in the full sun outside during the summer and brought in under frost free conditions during the winter, could be an interesting addition to your houseplant assortment.

PROPAGATION OF *PRUNUS TENELLA* 'FIREHILL' FROM CUTTINGS

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Abstract. The rooting response of *Prunus tenella* 'Firehill' to a combination of composts and growth regulators was evaluated. The growth regulators tested were the proprietory preparations of the combination of potassium salts of indole-3-butyric acid (0.5%) and naphthaleneacetic acid (0.5%) and of indole-3-butyric acid (0.8%) only. In addition, the rooting response to media mixes of two parts moss peat to one of sand (granitic origin), and one part perlite to one and two parts moss peat, respectively was noted. The potassium preparation produced rooting responses of between 44 and 76% and is a promising pre-propagation treatment for aiding root development of *Prunus tenella* 'Firehill'.

High rooting percentages (60 to 75%) were obtained with the potassium preparation where a 2P:1S mix was used. Results with IBA alone were poor in all composts.

REVIEW OF LITERATURE

References to propagation of this subject are sparse. Although *Prunus tenella* 'Firehill' is a plant of considerable worth (receiving an Award of Merit in 1959) its propagation, especially by cuttings, has received little formal attention. Attempts to propagate it by this means met with little success (3) and grafting produced 80 to 90% success with a slightly better result from field budding.

Previous work with softwood cuttings at Kinsealy (2) produced variable results. Here also, grafting success indicated a superior, though more complex system of propagation and resulting plants made rapid growth during the first season. Nevertheless, improved rooting resulting from a riper cutting (1) presented an opportunity for studying the effects of other factors like compost and growth regulators in the rooting process.

MATERIALS AND METHODS

Cutting Material. This trial was carried out in early July. The cuttings were taken from bushes grown outdoors in full sunlight. Each propagule was removed with a sharp knife by cutting through the junction of its attachment to one-year-old wood. This material was usually 12 to 15cm (5 to 6 in) long, and still in active growth. The soft growing point was removed.

The dominant type of current season shoots were longer and stouter than that described above. This growth inclined towards pithiness at its base, and being variable it was not used in the trial. Those cuttings being used in the test were placed in polythene bags after removal from the bush and were prepared by removing the lower two leaves from the stem base. No wounding of the propagation material was done.

Composts. As softwood cuttings in previous trials suffered severe basal rot when propagated under mist, the provision of an open and free-draining compost was considered necessary. Moss peat was mixed with a washed river sand, granitic in origin, in the proportion 2:1. Two further compost types were used, i.e. moss peat mixed with perlite in the proportions 1:1 and 1:2. As the cuttings were being propagated under light gauge polythene (25 microns) on a warm (20°C) bench the inclusion of such a high ratio of peat would ensure adequate moisture retention in the compost.

Growth Regulators. The standard against which other growth regulator treatments were compared was a powder containing 0.8% indole-3-butyric acid. Into this substance the basal 2.5 cm (1 in) of the cutting was dipped, and excess material adhering to the stem shaken off. The remaining formulations were: i) equal volumes of water and a combination of 0.5% potassium salt of indole-3-butyric acid (IBA) plus 0.5% potassium salt of naphthaleneacetic acid (NAA); and ii) three parts by volume of water to one part of a liquid growth regulator. In these compounds a fungicide and a synergistic additive were present. The precise nature of these is unknown. The base of each cutting was submerged in the preparations for a period of five seconds and, having been allowed to dry off for a further one minute, was inserted into the compost to a depth of 2.5 cm (1 in). After a light watering the trays of cuttings were placed in the propagation bench in an unheated glasshouse; shade material prevented all direct sunlight falling on the polythene covering.

RESULTS

During the propagation period the cuttings were ventilated once per week by removing the polythene cover for three or four minutes. During this operation, fallen leaves were removed and, when necessary, a light watering was given. The cuttings were lifted and recorded for rooting after 38 days. Table 1 shows the rooting responses to the various treatments.

Table 1: Effect of compost and growth regulator on the percentage rooting of *Prunus tenella* 'Firehill'. (Mean of three replicates of 15 cuttings per replicate).

Compost	Growth regulator		
	Water:K-salt[1] (1:1)	Water:K-salt[1] (3:1)	0.8% IBA
1 Peat : 1 Perlite	44%	60%	6%
2 Peat : 1 Perlite	51	67	6
2 Peat : 1 Sand	60	76	9
	Interaction : NS		
	LSD : 5% - 10.99		
	: 1% - 15.19		
	: 0.1% - 20.86		

[1]K salt of IBA and NAA

Both potassium salt treatments showed significantly (0.1% level) better rooting than the treatment with 0.8% IBA and significantly differ from each other at the 5% level, whilst in each respective compost the solution with the higher proportion of water gave the best rooting. There was no significant difference in compost/growth regulator interaction.

DISCUSSION

The use of the combination of potassium salts of indole-3-butyric and naphthaleneacetic acid dip considerably improved rooting in comparison to the use of 0.8% IBA used as a proprietory powder treatment. The low percentage rooting in the latter could not have been improved by extending the propagation period beyond that described, as all unrooted cuttings in this trial were dead at the time of recording.

A greater number of cuttings had decayed at the base where the concentration of the liquid growth regulators was higher, although rooting was satisfactory in this treatment also. The lower concentration of the liquid preparation in addition to aiding the percentage rooting, yielded root systems which were larger by 25% than the other treatments. This may indicate faster initial rooting where this substance was used as a prepropagation treatment.

The use of a compost comprising two parts moss peat to one of sand was an advantage. It was significantly better than both perlite composts. Although the variability in rooting success with *Prunus tenella* 'Firehill' appears to be related to the choice of growth regulator as a rooting aid, some significance must attach to the condition in which the cuttings remain whilst in the propagation bench. Serious deterioration of the material occurred in the warm bench and plastic system of propagation after about three or four weeks. Leaf drop commenced and this greatly lessened the possibility of rooting. It, therefore, appears that the role of a suitable growth regulator is associated with the speed of rooting and this reduces the danger of deterioration whilst this subject is being propagated from softwood cuttings.

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PROPAGATION OF *HAMAMELIS MOLLIS*

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Some years ago trials on the rooting of *Hamamelis mollis* were initiated at Kinsealy. While the rooting of the cuttings did not present a problem, the overwintering of the young plants did.

The cuttings were propagated by rooting in mist and also using warm bench and plastic. When weaned they were potted into 7.5cm pots using a peat-based compost containing 25% sand. The plants established well and filled the pots with a good root ball before going into dormancy. They were overwintered in a cold glasshouse.

By February the mortality rate was 100% even though water requirements, etc., had been carefully monitored. In later years we tried overwintering the plants at various temperature regimes including cold store treatment, but to no avail.

GRAFTING

It was decided to examine the traditional method of propagating this subject, i.e. by grafting on *Hamamelis virginiana*. We found it impossible to acquire understocks even from the normal suppliers abroad. They were not available even though they were catalogued. It was then decided to raise rootstocks from seed but again we failed to obtain even a small quantity. While collecting cutting material at the National Botanic Gardens, Glasnevin, we chanced to come across both *H. vernalis* and *H. virginiana*. We took cuttings of both which were rooted in mist. Both species were overwintered in 7.5cm pots and were grafted the following August.

The percentage of *H. virginiana* which overwintered under glass was considerably lower than that of *H. vernalis* (30% vs. 75%).

It had been reported that *H. vernalis*, when used as an understock for grafting *H. mollis*, was not suitable as it was prone to prolific suckering. At Kinsealy, we did not find this to be so; in fact, we found that imported plants worked on *H. virginiana* produced quite a few suckers during its early years after lining out. This may be due to clonal variation.

We have grafted many scions of *H. mollis* on rootstocks of the Glasnevin clone of *H. vernalis* over a period of years and have found that they make quite good plants.

Grafting Method. Rootstocks of *H. vernalis* established in Long Toms are taken from the glasshouse bench and trimmed back a little to fit snugly in a closed case. Grafting is done from mid-July to mid-August using the side graft method with a tongue. Rubber strips are used for tying the graft union which is not waxed. It is essential

to graft as close as possible to the roots of the understock to keep suckering to a minimum. The grafted plants are then placed in a closed case within a cold glasshouse. No bottom heat is used in the closed case.

Callusing of the grafts should be well underway within three weeks and hardening off should be complete by about six weeks when weaning should take place. When the grafts are fully weaned they are placed on an open bench in a cold glasshouse where they are overwintered. The stocks are headed back in the spring just as growth is commencing. A high percentage take (about 90%) is obtained.

Rootstock Production. At Kinsealy we have established a hedge of a single clone of *H. vernalis* from which we take our cuttings in early May. They are inserted in standard seed boxes in a compost of 2 parts peat to 1 part of a granitic sand. Forty cuttings are inserted per box. Basal cuttings are used, approximately 7.5cm long, which are placed in a solution of Captan (25gm in 5 l of water). They are taken out of this solution, allowed to drain for a few minutes and their bases dipped in an 0.8% IBA hormone rooting powder to a depth of 1.5cm. Rooting takes place in about three or four weeks either in mist or under plastic using a basal temperature of 20°C.

When well-rooted and weaned the cuttings are potted into 7.5cm pots using a compost of 2 parts by volume of fertilised peat to 1 part of granitic sand. The plants are overwintered in these pots in a cold glasshouse and must be kept on the dry side during dormancy. Overwatering during winter can be fatal.

When root development commences in spring (late April at Kinsealy) the plants are potted into Long Toms in which they will be grafted. A peat-based compost is used at this stage. If the plants are potted on too early before root growth has commenced many will be lost. Do not be tempted to pot on when shoot growth *only* is to be seen.

CONCLUSION

For a number of years we have found the above method of producing *H. mollis* in large numbers to be most reliable in producing good quality plants. We have tried seed which takes two chilling winters to initiate germination, but it is doubtful whether the plants produced are true-to-type.

It is possible to obtain early cuttings from *H. vernalis* by placing polythene bags over the stock plants in February. These early cuttings can give a reasonable percentage of young plants which may be grafted in August of the same year.

Spring grafting has been attempted at Kinsealy in past years using root sections and cutting of various other members of the

Hamamelidaciae but none has surpassed that of grafting in mid-July to mid-August on *Hamamelis vernalis* roots.

Finally, a word of warning. Young *Hamamelis* plants are very susceptible to attack by vine weevil. Every effort must be made to control it or the results will be most devastating.

PHYSICAL AND CHEMICAL PROPERTIES OF PEAT

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The understanding of peat compost and the changes that can take place in the compost throughout the growing season are important factors in producing quality nursery stock. Knowledge of composts can be summarised as follows: know your peat, know your nutrition.

Peat Types. Peat may be defined as a mass of organic matter at a stage of decomposition. Peat type depends on the source of plants and stage of decomposition. Sphagnum moss peat with which nursery stock producers mainly work is the final stage of a process which began approximately 10,000 years ago. Peat was laid down in a number of stages which may be divided as follows:

(a) Tundra conditions prevailed at the beginning with vegetation colonising higher ground. Arctic willow and birch formed the main woody plant life.

(b) Mixed forests of pine, oak, and yew gradually covered the areas above flood level while phragmites reed beds encroached the lakes. These constituted the first peat type.

(c) As lakes were filled in by reed beds forests began to encroach these areas to form "woody-fen" peat. These layers are composed of non-sphagnum mosses with woody remains, mainly birch.

(d) In the Central Plain area of Ireland when forests began decaying true acid bog peat began to grow. Thus true bog growth began and was succeeded by younger sphagnum composed mainly of relatively unhumified sphagnum mosses. This process is characterised by a complete absence of woody remains.

[1] Horticultural Officer, Bord Na Mona

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(e) The process of regeneration complex of young sphagnum gives rise to the raised bogs of the Central Plain. Sphagnum grows in hummocks with hollows between which form pools. As the hummock growth reaches a climax, growth ceases. The pool stage takes on a pronounced sphagnum growth outgrowing the original hummocks. This regeneration process raises the bog area.

Sphagnum Moss Peat Characteristics. The two most significant characteristics of sphagnum moss are:

(1) Sterile medium, i.e., free from harmful pests and diseases.

(2) Low salt concentration—it contains virtually no nutrition. Thus the user can add a known quantity of nutrients with the knowledge that all batches of compost are similar.

Sphagnum moss peat has a simple cell structure with a pH range of 3.8 to 4.3 (pH water extract 2:1).

The bulk density, a measure of mass, is low. This means the air- and water-holding capacity of sphagnum peat is high.

Sphagnum Species. The most common sphagnum species in Central Plain moss peat are both—

Sphagnum papillosum, and *Sphagnum imbricatum*, with *Sphagnum magellanicum*, *Sphagnum rubellum*, and *Sphagnum plumalosum* accounting for the remainder.

Nutrition of Crops. This is a most vital aspect of growing plants. The method of applying nutrients varies depending on the crop and the size of plant.

Propagation by cuttings or seeds requires small quantities of nutrition. Early formation of plants require a compost with low total salts but high in phosphorus.

Mature and long-term crops require a balance of major and minor nutrients listed later in this paper. These may be provided by supplying a longterm source or by liquid feeding. Nursery stock growers are adequately catered for in this regard with the availability of controlled release fertilisers. This nutrient advantage compared with other sectors of horticulture should not minimise the requirement for good management. This requires the grower to know what is taking place in compost throughout a growing season.

The addition of lime, nutrients, and the nursery water supply changes the characteristic of the original moss. The most important characteristics of composts are:

(1) Cation Exchange Capacity
(2) Fertiliser
(3) Lime
(4) Nursery water source

Cation Exchange Capacity (C.E.C.) This is the mechanism by which peat regulates the supply of available nutrients to the plants. A peat particle is surrounded by negative charges. To stabilise these charges, they require positive charges. These are obtained from added nutrients.

Plant nutrients applied to compost are composed of electrically charged ions, e.g. potassium nitrate comprises the potassium (K+) cation and the nitrate (NO_3^-) anion. The peat's negative charges attract the positive charge of the potassium which creates a stable balance. This balance is maintained until the plant requires potassium. This element is then removed from the peat and taken up by the roots. As peat contains large numbers of these exchangeable charges (120 meq per 100 ccm solid), it is an ideal material for the supply of nutrients.

Source of Nutrients. Plants get their nutrient requirements from two sources, lime and fertilisers.

Lime—Addition of lime has two roles in compost:

(i) It increases the pH, i.e. reducing the hydrogen ions in the peat, and

(ii) It provides calcium (Ca^{++}) and magnesium (Mg^{++}) for plant growth.

As both these elements are positively charged, they are held by peat by the Cation Exchange Capacity.

Fertilisers—The following elements are required in a compost for successful plant growth:

Major	*Minor*
Nitrogen (N)	Zinc (Zn)
Phosphorus (P)	Copper (Cu)
Potassium (K)	Iron (Fe)
Magnesium (Mg)	Boron (B)
Calcium (Ca)	Molybdenum (Mo)
Sulphur (S)	Manganese (Mn)

Nitrogen may be supplied in both the ammonium ion (NH_4^+) and nitrate (NO_3^-) form. Bacteria will convert the NH_4^+ to NO_3^- over a period of time. Due to the NO_3^- anion being rejected it may be leached from the compost. Nitrogen can be replenished by applying a longterm source of nitrogen to the base fertiliser or by liquid feeding.

As already described potassium, magnesium, and calcium have positive charges and are attracted to and held by the peat particles.

As phosphorus is supplied in the form of $P_2O_5^-$ which has similar characteristics to NO_3^- it is not held by Cation Exchange Capacity. It is normally replenished in a compost by applying a long term phosphorus source or by liquid feeding.

All minor elements are normally supplied as cations and are thus held by peat in the Cation Exchange Capacity.

Nursery Water Source. The source of water for nursery stock can have a profound effect on growth and quality of nursery stock. While water is essential for plant growth, the source of water can have an effect on the supply and availability of nutrients to the plant during the growing season (Table 1). In hard-water areas, there is an upward drift in compost pH over the season. This drift can make some nutrients, e.g. magnesium and trace elements less available.

Table 1. The pH of compost from two water sources projected over a season.

	April	*May*	*June*	*July*	*Aug.*	*Sept.*
Grower One	5.6	5.7	5.9	6.0	6.2	6.2
Grower Two	5.7	6.1	6.4	6.9	7.3	7.5

This increase in pH is due mainly to the presence in the water source of calcium and magnesium bicarbonates: the pH of the water is not a good indication of alkalinity as Table 2 shows.

The upward drift in pH in compost can make nutrients less available to plants. The element iron is a good example. This element is normally supplied to nursery stock as a chelate. There are a number of chelates on the market and their availability is dependent on pH. As the pH rises, the iron becomes more insoluble and hence unavailable to the plants.

Chelates readily available with their insoluble points are as follows:

Fe EDTA	pH 6	Fe HEEDTA
Fe CTDA		Fe EDDHA or
		Fe EDHPA pH 7+

Hence a rise in pH can make this element less available to plants, causing a reduction in extension growth during the season.

Composts made up at the start of a season can change over a period of months. To control growth, it is important to know what changes are taking place. The understanding of these changes can be an important factor in increasing the growth rate of plants and hence increasing gross margins at the end of the season.

Table 2. Volume of 72% nitric acid required to reduce the pH of water sources to 6.0 (Kinsealy Research Centre).

		S. C. of Water		
Sample	*pH*	*Before*	*After*	*Litres of nitric acid per 1000 gallons water*
1	7.35	52	58	0.930
2	7.30	21	25	0.310

PEAT-BASED COMPOSTS: THEIR PROPERTIES DEFINED AND MODIFIED TO YOUR NEEDS

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The diversity of the modern nursery stock industry inevitably means that any compost has to be "many things to many plants". Scientifically, the properties of a compost can be divided into physical, chemical, and biological. These can be interpreted to mean that the compost must provide a matrix which can physically support the plant, supply air and water, contain the chemicals which are required both as major nutrients and micro elements, and allow the microbes (required for the completion of biological cycles) to exist.

Due to the diversity of species being grown in any one compost on any one nursery there is a difficulty in defining precise levels of air, water, chemical, or biological activity. Generally a single mix is expected to "do" every species on a particular holding and variations in physical structure only occur among nurseries.

PHYSICAL PRINCIPLES

From the growers' point of view the most important properties of a compost will be the air-filled porosity, available water, and its bulk density. It is very difficult to achieve all the desired physical properties using a single material and usually mixes of two or more are used.

Air-filled porosity (AFP). The beneficial effect of higher AFP on plant growth was demonstrated by Paul and Lee in 1976 and recent trials work on hardy nursery stock in the UK has confirmed this. Not all plants require the same porosity (Table 1), which emphasises the need for specifically designed composts at least for the specialist producer.

Table 1. Minimum root aeration requirements. (Bunt after Johnson).

Very High 20%	High 20–10%	Intermediate 10–5%	Low 5–2%
Azalea	*Antirrhinum*	*Camellia*	Carnation
Orchard	*Begonia*	*Chrysanthemum*	Conifer
(Epiphytic)	*Daphne*	*Gladiolus*	Geranium
	Erica	*Hydrangea*	Ivy
	Podocarpus	Lily	Palm
	Rhododendron	Poinsettia	Rose
	Saintpaulia		

Currently within the UK three or four methods exist for measuring AFP and each method gives different numbers for the

end result. It is fair to say that within Western Europe there are ten to fifteen methods for AFP alone. The important end point is to relate measured AFP to growth and hence be able to index values determined in separate laboratories to avoid quoting individual figures. This would overcome the existing problem where a single compost could be given AFP values of 30%, 20%, or 10%, depending upon the method. If these relate to excellent growth, then they could all be classified as index 4 on a scale of 1 = poor to 5 = superb.

Available water. It is generally accepted that this represents the difference between container capacity and 50 to 100 cm tension equivalence. Much work has been carried out using a modified "Haines" apparatus by Bunt, and several French researchers. Other workers have chosen the pressure cell apparatus. All the methods have difficulties but, as with AFP, do have merit when clearly identified. Much more information is required in the near future because the increasing of AFPs to avoid waterlogging and increase available oxygen can have a profound effect upon the easily available water. (See Figure 1).

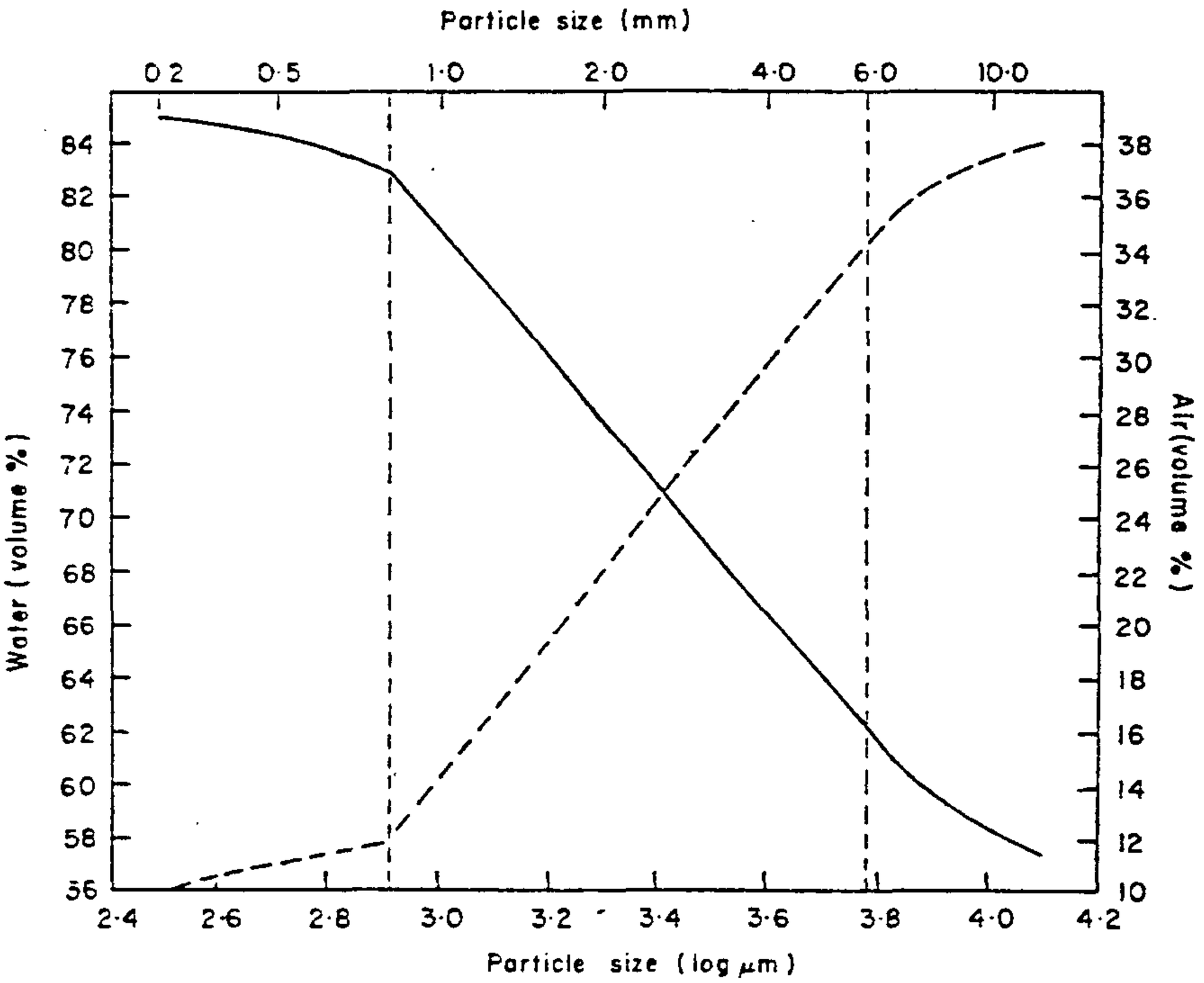

Figure 1. The influence of particle size on air-water relationship (after V. Puustjarvi). Solid line = water (volume %). Dashed line = Air (volume %).

Peat. Although peat remains the major bulk component of loamless composts, it is not universally uniform. Peats vary in age from the very young white peats of the Baltic through the highly decomposed sphagnum and sedges of the English levels. Each has differing properties which when defined will indicate their suitability for specific compost requirements.

Sand. Sand and grit are still being used to misguidedly "improve" drainage. In fact most sand and grit particles lodge in existing pore space so reducing AFP and impeding drainage. However, the addition of sand and grit increases bulk density which improves root anchorage and the stability of the pot. Very little work is being carried out to establish the ideal bulk densities for nursery stock subjects. Values less than that achieved in 75% peat, 25% grit/sand have proved very satisfactory. Where sands are used to improve rewetting properties of peats, then up to 5% by volume may be sufficient. For this latter purpose the particle size should be as small as is consistent with good aeration, perhaps between 0.5 mm and 1.0 mm. (See Figure 1).

The introduction of grit/sand into a compost also introduces another variable—calcium carbonate and its effect on pH. Horticultural sands should contain low levels of available calcium carbonate; pH is a very poor measure of this as can be seen in Table 2.

Table 2. Samples of sand used in UK horticulture (1985).

	pH	$CaCO_3$%	Dry Sieving % >0.5 mm	0.5–0.2 mm	<0.2 mm
(a)	8.2	0.7	47.4	38.8	13.8
(b)	8.3	1.3	63.2	36.6	0.2
(c)	8.2	13.1	51.3	44.5	4.2
(d)	8.6	79.1	74.0	22.6	3.4
(e)	8.6	0.2	47.5	39.2	13.3

Bark. Bark strippings from forestry which were once considered a waste product have now become extremely useful in increasing air-filled porosities of compost. Bark varies widely from hardwoods to coniferous sources. Some contain toxins which have to be dissipated by composting and others do not remain stable over time. Whilst the effect of the addition of composted bark (with or without added nitrogen) increases the structural stability of composts, little fundamental research on bark/chemical interaction has taken place in the UK. Much is made of buffer capacity yet no work has been done on barks currently available in the UK.

Rockwool. This water-repellent material is favoured highly by some nurseries and certainly, in terms of opening up a compost, there does seem to be considerable merit in its use. The material is not wholly chemically inert and reactions do take place with peat

which give rise to rapid pH alterations. This is still under investigation by Chambers and Bragg. Unfortunately, there is considerable consumer resistance and therefore use is often restricted to large scale amenity production.

Perlite. Perlite is an inert expanded volcanic ash, having an inter and intra capacity for water. The product can be obtained in all forms from ungraded to specifically graded products. High cost restricts its use to the propagation of nursery stock and pot plant production. However, its effect on AFP (Table 3) suggests that closer consideration of the material for larger pot work would be worthwhile.

Table 3. Air-filled porosity (A.F.P.) of Peat/Additive Mixes.

% Peat	% Additive	Fine Sand	3mm Grit	Coarse Bark	Perlite
100	—			12.8	
90	10	8.5	10.5	10.6	13.3
80	20	6.2	10.1	13.4	13.8
70	30	5.2	11.1	14.6	16.3
60	40	3.1	10.3	15.1	17.2

AFP value: Wolverhampton Rapid Method

Polystyrene granules. This is a waste product which when well graded will increase AFP. It is worthy of consideration as a dilutent if the cost is reasonable. Polystyrene has one major drawback—some samples contain highly toxic additives.

Vermiculite. The plate-like structure of this exfoliated mica allows it to hold and release large quantities of water. It has a high exchange capacity and contains available potassium and magnesium. Unfortunately, in nursery stock composts it is structurally unstable.

Surfactants and super-absorbent polymers. The chemical and physical effects of these substances are very complex and poorly understood.

Surfactants have been commonly used in peat-based composts to improve wettability. Although very effective for this purpose they are not long lived and may have to be reapplied during the production cycle. Some effects upon the chemical and physical make-up of the compost may be detrimental.

Super-absorbent polymers are capable of absorbing many times their own weight of water and a proportion of this is available to the plant. These materials may also be able to absorb and release plant nutrients and to improve the wettability of a compost. There is a trend that appears to show that polymers may increase AFP, although this trend has not been found to be consistent.

Durability. The physical durability of nursery stock composts is critical, especially where containers are exposed to winter rains on poorly drained standing areas. Not only must the physical com-

ponent give the required water/air relationship at potting, but they must be sufficiently durable to provide acceptable levels at the point of sale which could be 15 months later.

RECOMMENDATIONS AND FUTURE COMPOST SPECIFICATIONS

From current work in the UK, the following overall comments can be made. The smaller the pot, the younger the plant, and the poorer the watering and standing area, then a more open compost can be expected to give better results.

At Efford EHS, Margaret Scott has shown that propagation composts containing 50:50 peat/pine bark with low level fertilisers are consistently the best. These mixes should be altered to 70% peat, 30% bark for liners, and final potting with the incorporation of grit/sand and controlled release fertilisers.

In the future we must learn more about plant requirements. Composts can then be specified in terms of available water, AFP, bulk density, particle size and distribution, and particle shape and durability. A computer program can then be designed to provide the most economical blend of components to achieve this specification.

LESSER KNOWN PLANTS WORTH PROPAGATING

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The phrase, "lesser known plant" is an arbitrary one. A plant which is well known to one person may be rare to another. Plant material may succeed well in one part of the British Isles but may not be cultivated in another, even though soil and climatic conditions may be comparable. While preparing an inventory of trees and shrubs cultivated in Ireland and more recently at Glenveagh National Park, County Donegal, I have had an opportunity to examine several thousand trees and shrubs. Some are of botanical interest only but others deserve to be more widely cultivated. The taxa listed are in outdoor cultivation in this country and represent the floras of the temperate regions of the world. The plants selected have an ornamental value, such as flower, foliage, growth habit, peeling stems, or young foliage. They will succeed in any good garden soil and have little pruning requirements. Most are suitable for a suburban garden while the remainder could be planted in public parks or large landscape schemes. Some of the plants have been propagated but on a limited scale. Many are long lived.

LESSER KNOWN TREES

Lime trees, particularly *Tilia* × *europaea* are a common sight in our landscape. Less so are the Chinese species introduced in the earlier part of this century. *Tilia chingiana,* with a neat conical habit, glabrous ovate leaves, and sweetly scented flowers borne in midsummer, has grown to 12m in 40 years. *T. henryana,* another Chinese species, is similar in size and habit to *T. chingiana.* It has distinctive bristle-tipped leaves and flowers in September.

Both species are in cultivation at Birr Castle, County Offaly, where they are cultivated from seed supplied to Lord Rosse by the Lushan Botanic garden, Jiangxi, China. Unlike the European species they do not succumb to aphid attack.

Carrierea calycina, another Chinese plant is also cultivated at Birr Castle. This deciduous tree has large cordate leaves and a candelabra-like inflorescence of white flowers. Ernest Wilson, who introduced the species, considered that it had singular beauty of flower. Several attempts to propagate this tree by cuttings have been unsuccessful.

There are many cherries and crabapples worth cultivating besides the frequently planted *Prunus serrulata* 'Kwanzan' and *Malus* 'Golden Hornet'. The Siberian Crab, *Malus baccata,* forms a medium-sized round-headed tree with oval leaves and ivory white flowers. The flowers borne in April and May are succeeded by very

small fruit. Large pink flowers borne on bare stems in March and rich autumn colour are the outstanding features of *Prunus sargentii*.

Prunus yedoensis, Yoshino cherry is one of the most floriferous of the Japanese cherries. In March and April the stems are clothed in clusters of pale pink blossoms. At other times of the year the specimen at Kildangan, County Kildare, is notable for its graceful, arching habit.

CONIFERS WORTH PROPAGATING

Spruce, fir and pine are usually confined to specialised collections and forestry plantations. However, many deserve the attention of the nursery trade. *Abies koreana* is a small tree with a conical habit and thickly set leaves, which are dark green above and white beneath. When only one metre high it produces blue cones. There are many fine examples in the country of which the specimen at Kilbogget County, Dublin, must be the finest.

Abies delavayi is taller with an open branching habit, glaucous green leaves which form a distinctive V shape on the stem and large cylindrical blue cones. At Rossdohan, County Kerry, trees grown from seed supplied by the Earl of Rosse coned within five years of planting.

Picea likiangensis will attain a height of 30 m. It has an attractive habit with young shoots upswept at the tips, small leaves and bright red male flowers. The developing cones are also red and expand to 5 cm in length. There are several specimens of known wild origin at Birr Castle, County Offaly.

Pinus parviflora, Japanese white pine, is slow growing with a bushy habit. It is a 5-needled pine with leaves 3 to 5 cm long. The egg-shaped cones are borne in profusion even on young plants, and they remain on the plant for several years.

Taxus baccata 'Dovastonii Aurea' is one of the many cultivars of the common yew. It was raised in France in the mid-19th century. The shrubby habit and golden foliage give it year round appeal. There is a fine specimen at Mount Usher which was planted in 1888. *Taxus baccata* 'Dovastonia', West Felton yew, grows at Powerscourt, County Wicklow.

UNCOMMON SHRUBS OF NOTE

The Chilean fire bush, *Embothrium coccineum*, is frequently planted, but less so are *Grevillea* and *Gevuina*, also members of the *Proteaceae*. *Grevillea rosmarinifolia* is a medium-sized shrub with rosemary-like foliage and habit. The red flowers are held in terminal racemes and whatever the season a few blossoms can be seen.

Gevuina avellana, Chilean hazel, is a very fine foliage plant

with pinnate and double pinnate glossy green evergreen leaves. The specimens in Ireland form large shrubs to 15 m. White racemes of flowers are borne from August until early winter. They are succeeded by a hard, red fruit similar to an oak apple. There are notable specimens at Dargle Cottage, County Wicklow and at Mount Usher. The latter was planted in 1919 with material supplied by Slieve Donard Nursery, County Down.

Trochodendron aralioides is an attractive shrub with a tiered habit similar to that of *Cornus controversa*. The apple green leaves are held in whorls which are likened to the tree ivy. The infloresence borne in April and May is green with stamens arranged at the tip of a hemispherical calyx tube. An additional ornamental feature is the bronze-coloured young shoots. The specimens at Glenveagh National Park were planted in 1971 and have attained a height of 3 to 4 m. Seed sown in spring germinated successfully.

Illicium anisatum is a slow growing evergreen bush with cream-coloured flowers borne in early summer. The emerging leaves are bronze and expand to a dark glossy green. They are fragrant to the touch. It is a long-lived shrub. The two specimens at Mount Usher were planted in 1906.

Hydrangea aspera subsp. *sargentiana* forms a large, sometimes gaunt shrub with peeling stems and large hairy leaves. Flat corymbs up to 15 cm in diameter are borne in August and September and vary in colour from white through pink to purple. *H. aspera* though smaller in every respect is also worth propagating.

Another shrub with strong architectural qualities is *Senecio hectori*, a relative of the ubiquitous ragwort and groundsel. Out of flower the shrub resembles a luxuriant hydrangea. In July and August the large round infloresence of daisy-like flowers reveal its identity as a senecio. The shrub is defoliated in winter and requires protection from severe wind. This species was introduced from New Zealand by Major A. Dorrien Smith of Tresco Abbey Isles of Scilly, from whom E. H. Walpole of Mount Usher received a plant in 1908. There is also a fine specimen at Ballywalter Park, County Down. Hardwood cuttings taken in the autumn have rooted successfully.

Aesculus parviflora is a shrubby chestnut which suckers at the base to form a ticket of slender stems. White flowers appear in August. It is cultivated in many gardens and deserves to be more widely planted in amenity planting schemes.

Vallea stipularis is a tender South American shrub, suitable for mild localities. The pear-shaped leaves are a good foil for the small pink campanulate flowers. This plant has an unusual globose gnarled fruit. Propagation by cuttings has been successful.

The genus, *Rhododendron,* is widely propagated, but this propagation is limited to azaleas and hardy hybrids and rarely includes species. Many species have attractive flowers, young

growth, and peeling stems. A selection includes: *R. lepidostylum, R. camplyogynum, R. megacalyx, R. thomsonii,* and *R. bureavii.* Some of the large leaved species make good foliage plants.

A lesser known member of the Ericaceae is *Zenobia pulverulenta*. It has a thin habit and will attain a height of 1.5 to 2m. The glacuous green young growth and the lily of the valley-like flowers develop in July.

CLIMBERS WORTH CULTIVATING

The large flowered clematis such as *Clematis* 'Nelly Moser' and *C.* 'The President' are widely available but less so are the evergreen species *C. armandii, C., meyeniana,* and *C. balearica.* The latter species has dainty fern-like foliage, bronze when young, fading to dark green. Creamy coloured flowers are borne in winter. At Glenveagh National Park the plant grows in association with pyracantha. In 1914 Sir John Ross of Bladensburg, whose garden at Rostrevor, County Down had so many unusual plants, sent a specimen of this clematis to Mount Usher. This species was successfully propagated by cuttings inserted in a warm bench in spring.

Actinidia kolomikta is an attractive climber native to Manchuria and Western China. The leaves are purple when young and change to pink and white as the season progresses. There are fine examples at Mulroy, County Donegal, and Annesgrove, County Cork.

Dendromecon rigida is native to California. With thick, glaucous leaves and yellow poppy flowers, the shrub requires the protection of a sheltered wall. There is a specimen in cultivation against the wall of Malahide Castle.

The species and cultivars referred to here are in cultivation in gardens with botanical collections. With the cooperation of the garden owners I hope that the nursery trade will be able to make them available to local authorities, landscape contractors, and keen gardeners.

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HARDY AMENITY PLANT INTRODUCTION AND EVALUATION SCHEME

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Abstract. A vast gene pool of ornamental plant material exists around the world for nurserymen to exploit. New uses will be developed for many existing plants as physiological manipulation becomes more sophisticated. Several schemes which aim separately at more intensive use of current nursery plants, conservation of diminishing genotypes, and the exploitation of plant breeding techniques are described. The Hardy Amenity Plant Introduction and Evaluation Scheme (HAPIE Plants) aims to identify under-utilised plant material in botanical collections and subject this to commercial evaluation. Over a period of 18 months since the scheme was conceived 50 plant types with possible commercial potential have been identified. Batches in excess of 500 plants have been propagated of four types and distributed to cooperating nurseries. Another 8 to 10 types are in the process of large scale propagation.

INTRODUCTION

All industries require new products which interest customers, causing them to return and make further purchases. The nursery stock industry is no exception to this form of marketing. A continuing need for the industry is the introduction and promotion of novel plants which intrigue and excite the increasingly sophisticated and educated gardening public. Novel plants may arise from selection within existing types. However, this approach is only likely to give marginal but nonetheless often useful changes. In this manner many improvements to foliage shape, intensity of flower colour, or improved growth habit have been achieved.

Plant breeding programmes, depending on their size and intensity, can effect larger changes. These occur by hybridisation within species, across species and other genetic barriers, and can be achieved by conventional crossing or mutation breeding and, more recently, by genetic engineering. Such programs are expensive, long term, and require well-defined objectives in order to succeed. Breeders dealing with nursery stock subjects are more likely to succeed because their objectives need to be far less specifically targeted than is the case with food crops.

Alternatively, novel plants may be introduced from the wild or be rediscovered in existing plant banks such as those in botanic gardens and other collections. The United Kingdom is particularly rich in its heritage of extensive plant collections. These should not be stagnant gene pools but constantly growing and being replenished by the addition of plant material from all over the world. Within these collections exist a wide range of plant types including trees, shrubs, herbaceous plants, and alpines which have enormous potential for commercial exploitation. From these

genetic banks a vast range of plant material can be made available to the industry relatively quickly. For this to succeed introductions to the nursery stock industry have to be managed by a properly established plant introduction and evaluation scheme. Such schemes should select types with commercially desirable characteristics in terms of growth habit, leaf colour and shape, flower and fruit colour, and ensure that each introduction will fit satisfactorilly into current nursery stock production programmes.

Ideally introductions should be capable of being propagated in sufficiently large quantities to permit wide scale distribution in response to public demand stimulated by a national publicity campaign. On this basis the Hardy Amenity Plant Introduction and Evaluation (HAPIE) Scheme has been conceived.

PLANT INTRODUCTION SCHEMES

In the UK and Europe numerous collections of plant material are available. Most have been established over centuries of colonial activity by specialist nurseries and private and public bodies. In the latter group the most notable would be The Royal Botanic Gardens at Kew and Edinburgh (10). A fine example of a private collection would be Jermyns Gardens and Aboretum at Ampfield, Hampshire, started by the Hillier Family. From this collection a commercial nursery has thrived on the introduction of unusual garden plants. The nursery stock industry in Europe has used this collection for many years as a basis for reference (11).

Concern over the high level of growth variation within cultivars of nursery stock and possible implications regarding disease status led to plant health schemes being suggested for ornamentals (4). Studies showed that virus and mycoplasma infections were important factors in the growth characteristics of hardy ornamentals (7, 8, 13). Disease indexing would be a difficult and time consuming process for much of nursery material because of the vast diversity of types used. Micropropagation may be of some assistance in improving the health status of a selected number of plants, but it cannot be assumed to be effective for all viruses or virus strains (16). Indeed micropropagation has also revealed new problems. Endogenous and previously apparently symptomless microorganisms have been revealed by *in vitro* culture. The significance of losses to nursery stock caused by pests and pathogens has only recently begun to be assessed (9). Selection schemes which improved the health status of top fruit planting material are well documented (1). A similar UK scheme was initially launched by Long Ashton Research Station (5). Its main aim was to upgrade the general quality of nursery "bloodstock" by selecting within a cultivar (12). This is a plant improvement scheme, not an introduction scheme, and its success depends greatly on support provided by

nurseryman who donate plant material for growth comparisons (2). The Clonal Selection Scheme has now been transferred to East Malling Research Station, Mainstone, Kent (3).

It was originally envisaged that clonal selection could be linked to the establishment of national collections of genera throughout the United Kingdom. Establishment of national collections has now been undertaken by the National Council for the Conservation of Plants and Gardens (NCCPG). Conservation of genetic resources is of prime importance in the NCCPG Scheme (15). An important link should exist between conservation and plant introduction. Groups of plant breeders are actively improving nursery stock subjects at many centres.

Glasshouse Crops Research Institute (GCRI), Littlehampton, Sussex has developed a scheme aiming to introduce recently bred or selected material from world-wide programmes into the United Kingdom trade (D. Whalley, personal communication). By this mechanism important benefits may be derived resulting from research work in Europe, North America, and Australasia.

An industry oriented scheme designed to increase the diversity of commercially available plants, has been developed in Canada. This provides an effective utilisation of botanical gardens and a revenue source through royalties (14). By this scheme nominated plants are thoroughly evaluated by nurserymen with regard to commercial attributes before being subjected to propagation and husbandry tests. Additionally, plants are distributed to eight co-operating research centres throughout North America to provide data relating to growth in differing climatic regions and soil types. The Vancouver Botanic Garden propagates plants into units of fifty plants which are then sold under contract to individual nurseries. Each plant must be capable of giving at least twenty cuttings in the two years after purchase. The aim is to provide a minimum of 10,000 *cuttings in two years. This is a once-only introduction scheme*, although the Botanic Garden retains mother stock. Royalties are administered through the Canadian Ornamental Plant Foundation. Publicity is the responsibility of the Botanical Gardens. It is anticipated that two kinds of plants per year will be marketed under the scheme. Two successful examples so far have been *Genista pilosa* "Vancouver Gold' and *Microbiota decussata*.

HARDY AMENITY PLANT INTRODUCTION AND EVALUATION SCHEME (HAPIE PLANTS)

"HAPIE Plants" aims to identify potentially useful commercial plant types which are currently under-utilised and expose them to industrial evaluation. In proposing a UK plant introduction scheme it was recognized that two factors were crucial for success. Firstly, no commercial scheme could be viable without support

from nurserymen. The general support obtained so far has been highly encouraging and weighed greatly in decisions to continue with the scheme. Secondly, it is extremely important that a close liason be established at an early date with representatives from botanic gardens, plant propagators, and industry. This was achieved by the formation of a Steering Group representing the interests of research/advisory services, botanic gardens, nurserymen, garden centre trade and landscape sector.

It is the task of the Steering Committee to select plants for preliminary investigation. So far more than 50 plant types have been selected for evaluation. Plants are propagated at the North of Scotland College of Agriculture, Experimental Horticulture Unit (EHU), Craibstone, near Aberdeen. Macro and micropropagation techniques are employed and once sufficient quantities have been produced, batches of uniform plants are despatched to cooperating nurseries for evaluation under commercial conditions. Each nurseryman is asked to report on the plants, and this information will enable to Steering Committee to take decisions on whether or not to proceed with a particular plant.

At the nursery level very simple and direct questions are asked concerning the specific plants as shown by the draft report form as reproduced below. A far greater level of detailed evaluation will be made on plant material retained at Craibstone EHU, in particular studies of propagation, husbandry requirements, and tolerance to herbicides will be made. Once a plant has been evaluated a critical decision on further mass propagation will be made. This will then enable nurseries which are members of the HAPIE scheme to participate in promotion and sales.

Four types have been increased to at least the 500 plant level and are being distributed to cooperating nurserymen for their opinions. A further 8 to 10 types are being increased for further distribution in 1987.

Details of the mechanism for plant release are yet to be finalized. It is anticipated that interested parties may subscribe to the scheme in order to promote specific HAPIE plants. Publicity will be of prime importance in guaranteeing the successful introduction of particular lines.

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HAPIE DRAFT REPORT FORM (CONFIDENTIAL)

You will have received, or be receiving, plants for evaluation in this Scheme). On the basis of your experiences with this material over the next 12 months the Steering Committee would be grateful for the following information:

Assessor's Name .....

Address.....

.....

Plant name/code.....

	Poor	Good	Excellent
Overall Plant Quality			
Rate of Growth			
Overwintering Success			
Attractiveness of Foliage			
Attractiveness of Flowers			
Attractiveness of Berries			
Sales Potential			

Tick whichever box you feel is most appropriate.

Comments (give your views on the suitability of this material for inclusion in the *HAPIE Scheme*).

Return this paper to Mr. A. Blain, The North of Scotland College of Agriculture, 581 King Street, Aberdeen AB9 1UD *by 1 June 1987.*

Nursery), R. Mitchell (St. Andrews Botanic Garden), R. J. Smith (Springhill Garden Centre), and H. Weston (Civic Trees).

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PROPAGATE TO CONSERVE: A TALE OF NEGLECT AMONG IRISH CULTIVARS

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There is a rising clamour within Ireland and Great Britain, among the keener gardeners, for a more interesting selection of garden plants to be made available commercially. It seems to me, a botanist and historian of horticulture, that nurserymen only respond to the desire for interest and novelty by trying to produce more new cultivars, and they do not take the time to look back to those cultivars that are already available but not necessarily widely cultivated. The new awareness of the older garden plants has been fostered in Britain by the National Council for the Conservation of Plants and Gardens (N.C.C.P.G.) and by its affiliated group in Ireland, the Irish Garden Plant Society.

Think about this for a moment. In the nursery business, it is the *newly named cultivar that is the expensive plant—sometimes this* means little more than an unscrupulous nurseryman has renamed a plant, something which happens more frequently than perhaps we are prepared to admit. In many other businesses it is the older thing which is the more expensive—for example, antique furniture, vintage cars, antiquarian books.

I do not know the reason for this peculiar state of affairs in horticulture, but I do know that gardeners are now beginning to show their appreciation for the older cultivars and for the nurseries which propagate and stock such plants. I would like to think that nurseries understand this trend, but many nurserymen are still more intent on profit than on pleasing customers. That is perhaps a harsh thing to say, but the modern nursery trade has moved from trying to attract the interested customer, to trying to market as many plants as possible, as rapidly as possible, having propagated them as easily as it can. No longer does one hear of a nursery where one can wander around, select the plants one wants and arrange to collect them when they have been lifted and packed.

That was the old way of doing business and if one really wanted to please a favoured customer, a garden boy was strategically placed behind a clump or rhododendrons bearing a basket in which was reclining a bottle of the local fire-water! And in those days one Irish nurseryman advertised—note the subtle nuances of the order of words—that his was "the only nursery in Ireland worth a button, and is the most interesting nursery probably in the world".

The nurserymen of the 1980s have a lot to learn from their predecessors about advertising their wares, and indeed about the plants they should be plying to their customers. Nursery pro-

prietors are, I would suggest, in a unique position to fashion taste: give the customers an interesting and varied selection of plants and they will buy. You don't have to find the latest new blue rose or the yellow *Camellia* or a silver-rimmed *Omphalodes cappadocica* or even a variegated *Hypericum androsaemum* (although these all exist). Just look around at what is available in the gardens of keen amateurs.

Another point to ponder. The average garden—whatever that may be—contains perhaps 500 different plants (indeed that is probably a high figure). (The gardens of the keenest gardeners will, of course, contain many more plants—the great Irish naturalist and one time unofficial head-gardener at Dublin Zoo, Robert Lloyd Praeger, reckoned he had 250 species in one small portion of his rock-garden and that certainly is not exceptional.)

Even if each of the putative 500 plants was a different cultivar of Irish origin, that still would leave over 500 cultivars of Irish origin for another gardener to cultivate without any duplication. But sadly of those 1000 Irish cultivars—that is the approximate figure which I have computed from my register of cultivars raised in Ireland—less than one-third still survive. It should be noted that the figure of approximately 1000 does not include *at least* another one thousand named daffodils (including 'Lucifer' raised by Mrs. Alice Lawrenson about 1900, Mrs. Kate Reade's recent 'Foundling' and many others), and a further 1000 named roses; Irish nurserymen were and are the world leaders in the raising of cultivars of *Rosa* and *Narcissus*.

Where have the missing plants gone? Why are they not available in nurseries and garden centres?

Some are very difficult to propagate. It would be wrong to pretend that the Slieve Donard's incomparable selections of *Dierama* are easy plants for any nurseryman to handle. They do not tolerate transplanting readily and, as they have to be raised vegetatively, to maintain the true cultivars, they cannot be increased rapidly. Perhaps this is a genus which could be studied with a view to attempting some form of tissue culture, for the Donard cultivars of *Dierama*, with the names of birds—'Blackbird', 'Heron', 'Windhover', Snow Goose' (all tall forms)—and with the names of characters from *A Midsummer Night's Dream*—'Titania', 'Oberon', 'Miranda', and 'Puck' (all dwaft cultivars)—are almost entirely lost.

The Slieve Donard Nursery's other plants have fared somewhat better. It is principally known for its magnificent *Escallonia* cultivars—'Apple Blossom', 'Peach Blossom', and the Donard series, e.g 'Donard Beauty' and 'Slieve Donard'. These are still excellent plants for small garden and are especially suitable for coastal gardens and as hedging. Most, if not all, still survive and some are regularly offered by the trade. But, I would like to see somewhere a

full collection of these plants established here in Ireland as a conservation and reference collection with accurately identified and named cultivars; it must include introductions such as *Forsythia* × *intermedia* 'Lynwood' and *Hypericum* 'Rowallane' as well as the nursery's own originals. There are plans for such a Slieve Donard collection in Northern Ireland, under the care of the National Trust, but progress is slow and every year lost admits for the possibility of another lost plant. The Northern Ireland Heritage Gardens Committee hopes to promote this idea more vigorously in the coming year.

The urgency of establishing such a reference collection can be illustrated by the following tale. In May, 1986, at Newcastle I was surprised to discover a series of not less than seven *Rhododendron* cultivars raised and named, but not validly because the names were not registered with the International Registration Authority by the Slieve Donard Nursery. These have now been taken into care by a local nursery and I am confident that the cultivars can be perpetuated. 'Grand Gala' and its unnamed sister are magnificent plants; 'Evelyn Slinger' has a unique colour and a marvellous full flower. The others need to be propagated and tried in a few other gardens before final judgements can be made, but these are part of Irish heritage of fine garden plants and without a concerned nurseryman they would be lost.

The Slieve Donard Nursery ceased trading in 1974. It had served Irish gardens for over half a century and had produced a series of superlative plants. Although not its own, *Meconopsis* × *sheldonii* 'Slieve Donard', is undoubtedly the best of the perennial blue poppies—it has many imitators and a host of imposters and that surely is the best recommendation. Could you imagine Irish gardens without it? Yet it is another plant that is slow to increase and will be lost if dedicated gardeners and nurserymen do not keep it and increase it vegetatively.

There are and were other Irish nurseries with as fine a tradition. In 1987 Daisy Hill Nursery in Newry is a century old. Its founder, the English-born horticulturist, Tom Smith introduced the Japanese October cherry, *Prunus subhirtella* 'Autumnalis', to Europe—a fine plant, not as spectacular as *Prunus serrulata* 'Kwanzan' but, in my opinion, it is much to be preferred. *Aconitum* 'Newry Blue' was produced by Daisy Hill and again it is flattered by its many imposters. I am told that this is raised from seed in Germany, but that is quite impossible as it is a clone and has to be increased vegetatively.

A whole series of *Bergenia* cultivars came from Newry before the end of the last century. A few survive in gardens and this is one case where I would have to say that the old cultivars are not as good as the newer ones. Yet can any modern cultivar beat the true *Bergenia* 'Ballawley', rised by Desmond Shaw-Smith of Ballawley

Park in South Dublin? I don't think it can—liver-bronze leaves in winter turning emerald green in spring, an excellent ground-cover plant and one which also manages to produce lustrous magenta flowers.

Laburnum alpinum 'Newryensis', which was introduced from Daisy Hill Nursery, is not a plant I can recommend with my whole heart because of the poisonous seeds, but as a tree for a garden where children are not a concern, it takes some beating, because it is late flowering. It is extremely rare in cultivation. There is a plant in the National Botanic Gardens, Glasnevin, from which An Foras Taluntais (Kinsealy) obtained scions for grafting; this was successful and we have been able to resupply the Newry nursery and also the National Collection (designated by the N.C.C.P.G.) of *Laburnum* at Powys Castle in Britain. It blooms after all the other *Laburnum* cultivars; indeed it looks dead until mid-June.

As far as the Daisy Hill Nursery's plants are concerned we are in a sorry state. Very few now survive—*Ribes sanguineum* 'Splendens' is in cultivation, but has been replaced by cultivars with larger inflorescences. *Primula* 'Our Pat' is available in a number of nurseries in Northern Ireland, but where have all the *Aster* and *Trollius* cultivars gone—perhaps they were not disease-resistant? But not all old cultivars are weak; some older plants may have qualities that could be valuable in future breeding programmes—disease resistant, for example—and their loss diminishes the gene-pool, quite apart from depriving gardeners of older cultivars. The conservation of garden plants is not merely a matter of sentimentality; it should be a matter of concern for all those interested in better gardens.

What other Irish cultivars should be propagated more widely, and be made better known again? *Papaver* 'Fireball' has had some considerable publicity recently in *The Garden* under its invalid name 'Nanum Flore Pleno'—a mouthful that I was only too pleased to point out was unnecessary! It is available occasionally in Britain, but I have not seen it offered by an Irish nursery. It is perennial, spreads quickly by underground rhizomes and should be easy to propagate. *Rosa* 'Souvenir de St. Anne's', a branch sport of 'Souvenir de La Malmaison' noticed by Andrew Campbell, head gardener at St. Anne's, Clontarf, at the beginning of this century, has been praised highly by the doyen of British rosarians, Graham Stuart Thomas. It flowers from May until Christmas, is hardy, does not need coddling, and grows well on its own roots. Besides that it has elegant shell-pink flowers and a strong fragrance. But it is not a modern rose and so, because in the rose world nothing more than ten years old is considered any good, it is rarely propagated. But it roots quickly and grows strongly. One Irish nurseryman is propagating it and finds it easy to market.

Concerning Irish roses, it saddens me very much to think that

hundreds of native cultivars are no longer grown. It saddens me even more to think that the great rose nurseries, Dickson's and McGredy's have no interest in keeping their historic plants. Where is 'Irish Beauty', 'Irish Fireflame', and the whole series of unique single hybrid-tea roses raised at the beginning of this century by Dicksons of Hawlmark? With great difficulty I found one, 'Irish Elegance', for Wendy Walsh to paint as the final plate in the second volume of *An Irish Florilegium*. Might we see one day not just rose trial gardens, but also a conservation collection of Irish roses with the best of the older cultivars preserved for posterity? Not all need be kept, but some at least should be propagated and preserved.

I have mentioned so far mainly trees and shrubs and, of course, there are many herbaceous cultivars too. Ireland was known early this century as a land of primroses where "little old ladies" kept secret gardens brim-full of all sorts of lovely primroses. Very few of these survive; vine weevil and viral diseases have taken a heavy toll, but whose which do exist still are worth the trouble of keeping. 'Guinivere' has many good qualities and is still abundant but not on sale; 'Rowallane Rose' is a superb candelabra primrose that is sometimes listed in Britain but again not here. Has anyone seen a nurseryman offering genuine *Schizostylis coccinea* 'Mrs. Hegarty', or *Saxifraga* 'Ballawley Guardsman' recently—more plants much flattered by hosts of imposters. The genuine articles are extant, but not on sale despite what may appear in garden centres.

That, of course, raises another problem. Many nurseryman do not bother to check the authenticity of plants that they sell. In recent years I have seen plants of the native heather, *Erica* × *stuartii*, widely sold in Ireland and Britain and labelled 'Irish Lemon', but very, very few of the plants were correct. That cultivar is unmistakable having lemon yellow young shoots in early summer. That is just one example. The problem of cultivar identification and verification is difficult and complicated. It has not been helped by historically unsound cultivar selection schemes which take no account of taxonomy; in some of these schemes there was no attempt made to verify the plants submitted for trial or to obtain original, authenic stock. Thus the final selection could have been a cultivar quite distinct from the putative trial plant. Many cultivars (of perennials and woody plants) are clonal in nature and must be propagated vegetatively; because they are genetically uniform (each one is a clone) it is impossible in biological terms to subject them to selection. If there are differences apparent during a trial these may be due to diseased stock, to the mixing of stock, or to the misidentification of plants.

But I have digressed into another topic, the correct naming of plants, and I should return to my purpose. Over the past two and a half centuries Irish gardeners and nurserymen have produced some of the finest garden plants available to gardeners in this part of the

globe. It is our duty as the current gardeners and nurserymen to see that the best—at least the best—of these plants remain in cultivation. I am not suggesting that Irish nurseries should stick only to Irish cultivars, for in this harsh world that would be suicidal. I seek merely to point out that we have a heritage of outstanding value and excellence in all fields of horticulture and that we should be proud of the achievements of past generations. Many of the older plants make superb subjects for modern gardens and should not be despised because they have been "around for a long time"—like the best wine, age should give them a glow of quality. Antique plants can be beautiful and interesting, and from the nurseryman's point-of-view, they can also entice appreciative customers. They are certainly plants to be cherished and propagated again.

I, therefore, plead that nurserymen should not neglect the older cultivars. They can add lustre to gardens and create interest. Would it not be nice to be able to say again, as Tom Smith did with such succinctness, that Irish nurseries are the most interesting nurseries *probably in the world*?

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THE FRENCH WAY TO PROPAGATE PLANTS

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This paper will be confined to a discussion of cutting propagation at the Andre Briant S.A. Nursery in France.

MOTHER STOCK

The cuttings originate from three different sources, namely:

- Field-planted mother stock cultivated uniquely for this purpose.
- Mother plants grown in tunnels, which permits the forcing of plants, to produce cuttings which are more tender in a shorter time.
- Finally, young plants themselves grown in our small pots.

Which are the best cuttings? In a lot of cases the cuttings are better and root more quickly when they are produced in the tunnels or from young plants, as the younger material gives better rooting.

This is true, for example, for all cultivars of: *Malus, Betula pendula, Prunus serrulata,* Molle hybrid azaleas, and many others.

On the other hand, this young material is very sensitive to excesses of heat and humidity. This is particularly true for certain plants such as *Hypericum calycinum,* for instance.

Also, once very herbaceous cuttings are rooted they are no longer supported in an atmosphere which is entirely "suffocating". Therefore it is necessary to be able to aerate them at this precise moment. It is then desirable or even imperative to have only one type of cutting in the same tunnel.

In total, the percentage of cuttings, in relation to their origin, is the following: 70% from field-planted mother stock, 10% from outside sources or different gardens, 10% from young plants, 5% from tunnel-grown mother stock.

The material for cuttings is often brought in from a few kilometers away, to the place where they are made. In general, the wood is cut in the morning, then kept in the coldstore for a maximum of two days for herbacous material, or a few days to a week for evergreen material.

Conifers can be stored for a greater time without damage at 0°C and 90% humidity (for two or three weeks). In storage, all the cuttings are covered with plastic sheeting.

HOW THE CUTTINGS ARE MADE

Without exception the cuttings are all made with the aid of secateurs. The speed of operation varies according to the ability of the worker, and also with the plant species.

The average speed of preparation is about 450 cuttings per hour, but varies a lot, for example: 180 cuttings per hour for *Berberis* vs. 700 cuttings per hour for *Cotoneaster dameri* 'Skogholmen'.

The quality of the cuttings depends a lot more on the choice of the branch, which must not be too thin or too thick, than on the quality of the cut.

A good worker is expected to have not only good dexterity, but also good judgement. He must be able to choose quickly from the pile of material before him the best branches from which to take the cuttings. This must be done without wasting time. On the other hand, if it is a question of juvenile material, the choice of branch is a lot less important, and the only concern is the speed of the execution.

The operators charged with making cuttings are placed in front of a little table, one behind the other. On their right, a long table joins all the small individual tables. On each long table is found the material for cuttings; the finished cuttings are placed in little piles on the left of the worker. It is absolutely crucial that the waste falls gradually to the floor, so that good vision can be maintained for the work being done, and so as to have cutting material only in front of the worker.

One person is assigned to apply the hormones to the cuttings. This person passes before each operator with a trolley on which are found the storage boxes, the hormones, the fungicides, and the labels. The piles of cuttings are gathered together, dipped in the hormones and regrouped in rows in the boxes in a way that allows the planters to pick them up easily. As a general rule, a label is attached to each box. The person in charge of this controls the cordination of the procedures and estimates the quantities.

The hormones used are the following: Rhizopen AA (0.5%—1%—2%), pure liquid Exuberone, and Exuberone powder H.

We mix a fungicide with the hormone according to the situation and the different percentages. As far as we are concerned, the choice of hormone does not depend on the species or the cultivar, but on the vegetative state of the cutting (with rare exceptions).

INSERTION OF CUTTINGS

After the application of hormones, the cuttings are held in the coldstore, the boxes being stacked and arranged according to species and cultivars—one row equals one cultivar—in a plastic cupboard with partitions which allows storage at the necessary humidity for good conservation. They are planted the next day.

The cuttings are inserted either in cellular trays or directly in frames. In both cases, the planting is done in the tunnel. The making of the cutting and the planting are therefore two well separated operations carried out in different places.

The use of cellular trays offers two principal advantages: Firstly, it facilitates the selling of the rooted cuttings. The cuttings are therefore of better quality for selling directly than bare-rooted cuttings. They are easier to transport and store. Secondly, it facilitates the use of potting machines for further planting into pots or containers.

Propagation in multipot trays allows repotting at a less imperative date than if we used bare-root cuttings. Thus, we are less concerned about a possible delay in the originally planned repotting programme. The cuttings from cellular trays start to produce new roots almost immediately after repotting. This type of propagation gives an important saving in hand labour and volume of substrate.

Equally, there is a saving in labour in the transference of cuttings from the propagation sector to the repotting site. The multipot trays allow us to have better control over phytosanitary problems, as there is less contact among cuttings themselves and an easier isolation of sickly cuttings.

It is necessary to know, however, that the propagation in trays is not the same as the propagation in frames. The behavior of cuttings is very different. The needs in humidity, for example, are totally different. It is a question of adapting oneself to the new demands of our cuttings. Having disturbed them in their habits it is necessary for us to catch up and quickly meet their new requirements.

The cost of production is very similar for a cutting in a cellular tray or one in the frame. But we still use the frame planting technique for the cuttings which, subsequently, have to be planted in the open field. On the other hand, it is necessary to note that the cuttings in the cellular trays are much more sensitive to winter cold and that they, therefore, demand important protection and sometimes the use of an antifreeze heater.

GREENHOUSES AND TUNNELS

We only use double-skinned polythene tunnels with lateral windows for aeration. These tunnels are eight metres in width and thirty metres in length. It is possible to plant up to 110,000 cuttings per tunnel.

The substrate used consists of 50% fine Irish peat and 50% sand from the Loire Valley. The same substrate is used in the frames as in the cellular trays. After mixing and preparation, the medium is sterilized with methyl bromide. In the frames, the medium is changed every two or three years.

The cellular trays are filled with substrate near the tunnels with the aid of a special machine built for this purpose. They are then transported on pallets to the tunnels where they are unloaded onto a flat black plastic canvas. At the time of planting, a board is placed

across the trays, and the planters stick the cuttings kneeling on this board.

All the tunnels are white-washed with a chalk-based paint to avoid scorching in hot weather.

IRRIGATION

Two types of irrigation are used:

Mist System. This actually is a fine watering controlled by a central clock through an electromagnetic valve and programmed in advance. The watering lasts for about 10 sec. It comes on once a day in cloudy weather, and eight times a day maximum in very hot weather. Between these two extremes, all other variations are possible.

We can also water manually if, at a precise moment during the day, the necessity arises for one or two tunnels only. This system has been used for ten years, and has been entirely satisfactory for most species and cultivars of shrubs and conifers. It has proved to be a very economical system.

Fog System. The fog system is a new technique which we have been using for four years. The fineness of the fog is obtained by mixing air under pressure with water. This allows a high hygrometrical degree to be maintained in the greenhouse without using too much water. It is a technique which is perfectly suitable for herbaceous cuttings in June, July, and August. The trials that we have done on conifers have proved equally successful. However, given the increased cost, we use it only for the first three weeks of rooting herbaceous cuttings. After that the conventional mist system is used.

Maintaining humidity at almost saturation without any dripping water on cuttings is the main advantage of the fog system. Considering the fact that many species respond to an ambiant humidity of 100%, but do not tolerate water on their leaves, this technique seems ideal. The results tend in effect to prove it.

It should equally be observed that fog permits us to work at high temperatures without burning, as it gives a certain amount of shading. To be exact, however, it is better to add to the fog one or two waterings for a maximum of about 10 seconds.

ADDITIONAL COMMENTS

Supplementary heating is very seldom used. We try to use solar energy as much as possible. However, in the future we are thinking of using surface heating, especially for the propagation done at the end of autumn, in winter, and at the begiinning of spring. This supply of bottom heating is not, in general, essential to rooting, but it speeds the operation, particularly for evergreen species.

Gradual weaning of the cuttings is very important. Exposure to

the open air is one of the tricky points. It has to be done very gradually, neither too late nor too soon.

The speed of rooting is variable, it may be a few days for *Buddleia, Perovskia, Lespedeza,* and miniature rose-trees, to a few months for × *Cupressocyparis leylandii, Taxus,* and *Picea* (in the colder months).

The success depends equally on the year and the species and, of course, it is linked to the weather conditions at the moment.

Our average success rate last summer was about 80%, on more than six million cuttings, but we lost 5% over the winter.

Our programme of cuttings production is as follows starting with the month of May:

May:	Take cuttings of conifers such as *Thuja* and × *Cupressocyparis*.
June, July:	Take herbaceous cuttings of deciduous species
August:	End of herbaceus cuttings—beginning of cuttings of evergreen species.
September	
Oct.–Nov.:	Root cuttings, without bottom heating, of evergreen species of trees, including conifers, and shrubs.
December	
Jan.–Feb.:	Root cuttings of conifers and other evergreen species using bottom heat.
March	
April	

I have not mentioned the acclimatization of the *in-vitro* cultures as this technique is being constantly refined.

The *in-vitro* cuttings are delivered in wide-mouthed bottles. At the moment about 20% of them are rooted—for example: *Rhododendron, Cortaderia,* and so on. We plant them out into cellular trays like the conventional cuttings, and place them under a 50 micron plastic film. A single watering has to take place whilst waiting for rooting. This is done at the time of planting out. The plastic film is lifted a few hours a week to change the air. Up until now, we have been satisfied with the method of weaning *in-vitro* propagules. But, it is necessary to be on guard against diseases which spread very quickly on these especially fragile cuttings.

HERBACEOUS PLANT PRODUCTION AT BLOOMS OF BRESSINGHAM LTD.

GORDON HARDY

Blooms of Bressingham Ltd.
Bressingham, Nr. Diss,
Norfolk, England

The company employs approximately 180 to 190 staff throughout the year with some seasonal fluctuations. The herbaceous growing side of the company has three main departments where we have a relatively fixed staff.

In the open ground 110 acres are farmed and rotated with arable land every two years. A great advantage we have is a wide range of soil types in such a small area: fen peat, sands, gravels, heavy clays, and good loams. The department has a regular staff of 22 people which do mainly seasonal work, e.g. hoeing, planting, splitting, and order-lifting for despatch once the season starts, i.e. September to April.

In the container department, with 950,000 plants being potted, we have a fixed staff of 5, dealing with 5 acres of standing ground with some seasonal fluctuations in staff. They mainly deal with despatching orders, growing on, and watering the plants.

The propagation unit and stock growing area has 9 fixed staff which supply material both to the open ground and container departments for growing on for sale. The unit grows plants from seed, cuttings in cold frames, tips in the mist, and root cuttings.

The herbaceous section thus has 36 full time staff which remains fairly constant throughout the year.

THE OPEN GROUND SECTION

This section starts its main propagation from divisions in December when bulk items are lifted for storing in a facility which is frost-free.

December. We lift 3 bulk crops with approximately 70 to 80,000 *Astilbe* which are put into winter storage. *Hosta,* approximately 100,000 for winter splitting, and *Hemerocallis* 50,000. We also lift, for winter storage, corms of *Crocosmia* and these are dried and sorted and then replanted the following spring.

January onwards. We start propagation on these 3 items: Hostas are probably the most interesting; we are using a technique devised by Maurice Prichard when he worked at Bressingham. We take out the apical dominance of a crown bud and slice the remainder into quarters. There is no treatment after this. The normal divisions are put outside in trays and we plant them when they begin to shoot. The cutups are laid in beds outside until they shoot in June and these are then planted. These beds can be

protected in very cold weather by covering with a floating plastic material. This conventional method is too slow to bulk up cultivars quickly. Therefore, micropropagation is being used more now, on new cultivars such as *Hosta* 'Halycon', which has a good blue foliage. *Hosta* 'August Moon', is a good late colouring golden cultivar. *Hosta* 'Krossa Regal', is a quite outstanding upright blue/green foliage cultivar.

Astilbes. These are propagated by a straightforward splitting operation. We have one or two ouatstanding cultivars—the best is *Astilbe* 'Snowdrift', a nice intense white flowered cultivar. Old favourites are 'Fanal', good, deep red, and 'Federsee', a cerise pink. Look for some interesting dwarf cultivars to be introduced. *Astilbe simplicifolia* 'Sprite' is now readily available.

Hemerocallis: We have a considerable number of new cultivars coming on: *Hemerocallis* 'Bejewelled', two-toned pink; *Hemerocallis* 'Canary Glow', an orange-yellow; *Hemerocallis* 'Luxury Lace', a fine pink; and *Hemerocallis* 'Cherry Cheeks', a nice red.

Propagation, in the conventional way, takes place in January. The plants then stand outside in trays, covered with straw. After they shoot, the covering is taken off and the crop is planted as soon as we can get on the land.

February. There is a slight delay in propagation as orders take precedence in February, but our "rough split" plants must be done. These can then be planted in March or April. *Geranium pratense*, *Geranium* × *magnificum*, *Geranium* 'Claridge Druce' and *Geranium sylvanticum* types will take fairly rough handling. *Iris sibirica* cultivars can also be done at this time. *Iris sibirica* 'White Swirl' is a clear white. *Iris sibirica* 'Persimon' is a large-flowered deep purple. *Ligularias* are easy to handle. *Coreopsis verticillata* 'Grandiflora' can be done at this time, too.

March. We will carry on with the *Trollius* and then the *Aconitum* which, as soon as they start to shoot, must be split. *Aconitum* 'Ivorine' is a good, white-flowered cultivar, which can also be propagated from seed in some years.

Dicentra spectabilis and *Dicentra spectabilis* 'Alba', as soon as they show above the surface, must be pulled down with hammers and planted immediately.

Tradescantia cultivars are done in March, too. Pulmonarias can be done either in January before they flower or after they flower in March. Useful cultivars are: *Pulmonaria saccharata* 'Argentea', *Pulmonaria angustifolia* 'Azure' and *Pulmonaria saccharata* 'Highdown'.

April: We deal with the softer cultivars which should be taken and planted the same day. *Chrysanthemum* × *maximum* 'Wirral Supreme', the dwarfer *C.* × *maximum* 'Snowcap', and the *Erigeron* cultivars are very impressive, early summer-flowering plants and

quite dwarf. *Astrantia major, Astrantia* 'Marjery Fish', *Astrantia major* 'Rubra' and *Astrantia major* 'Rosea' are ideal cut flower and dried flower plants. *Centaurea,* 'John Coutts', *C. dealbata* 'Steenbergii', *Allium schoenoprasum* 'Forescate' can also be done in April.

May: We have rounded up the majority of plants in the field.*Geranium* 'Johnson's Blue', *Geranium* himalayensis (syn. *G. grandiflorum* var. *alpinum*), and *Geranium grandiflorum* 'Plenum' will take winter splitting, but we like to leave them until they have grown in the spring before we do so. *Geum* 'Georgenberg' and *Geum* × *borisii* can be split and taken as cuttings, or divided and field-planted. *Knifophia* can now be done. *Aster, Monarda, Sidalcea, Stachys oenothera* (the evening primrose), and *Achillea millefolium* 'Cerise Queen', can also be propagated now.

June: We like to have cleared the field by now of the 2,000 different cultivars which have to be done. The odd ones, like *Gaillardia, Schizostylis, Doronicum,* and *Caltha palustris* 'Plena' are still left to do as they flower early so are dealt with later.

July: The May flowering, dwarf iris can be lifted, split then replanted on a 2-year bed system to allow them to bulk up in the first year, then in the second to split and flower and grow.

August: The tall, bearded iris and *Paeonia lactiflora* cultivars are done on a 2-year bed system. Two-year bed plants are: *Iris pumila,* tall, bearded iris cultivars, *Hosta, Paeonia lactiflora, Agapanthus,* and *Crocosmia.*

GROUND PREPARATION

Ground preparation is done by various machines, a "shaker-racker" vibrator breaks up any subsoil pan there may be. Power harrows or ordinary tines follow.

A base dressing is put on; up to July 300 lbs per acre of 16/8/24 fertilizer is put on. After July we put 329 lbs per acre of 20/8/14. This is a base dressing on mineral soils; a top dressing of 25/16 of 160 lbs per acre is used for the earlier plantings.

PLANTING:

We use a 5-row Accord Planter which plants on 6 ft. beds at 11 in. centres; the approximate rate is 25,000 plants per day. Once the machine has gone through there is quite a ridge which can be a problem; the ridge is then levelled using a lillistrum. Once levelled the spray department seals the crop on the ground using Venzar.

Some plants do not need any spray, e.g. Scabius, *Phlox, Papaver orientalis, Pulmonaria,* though some will take Enide. Betanole has been used as a high pressure spray in the cool of the evening especially on cultivars that cannot be sprayed with a pre-

emergent herbicide. Later in the year a hoe has to be used, but with labour being so expensive we have to rely on herbicides more and more.

PROPAGATION UNIT:

This is separate from the open ground splitting. It has its own staff of nine as previously mentioned. This is where all the cuttings are taken and grown: tip cuttings using mist, heel cuttings using traditional cold frames, and root cuttings.

Cold frames are mostly covered by Dutch lights now but some are modified summer frames covered with polythene stapled onto wooden battens. Lavender, *Geranium* × *riverslexianum* 'Russell Prichard'. santolinas, rosemarys and *Sedum* 'Autumn Joy and S. 'Ruby Glow' are put in cold frames. Cuttings are put into the soil in these frames which is a sandy mix with extra peat and grit worked in. There are 1,000 cuttings per Dutch light so each frame could hold 30,000 cuttings.

The propagation year would start in September, with root cuttings of *Papaver* which are ready for planting in March.

In October we would start certain grey-foliaged cultivars e.g. *Artemisia, Lavandula, Rosmarinus, Santolina chamaecyparissus,* and *Salvia officinalis.*

In November we are preparing heeled cuttings of *Geranium* × *riversleaianum* 'Russell Prichard', *Potentilla* cultivars such as 'Gibsons Scarlet', 'Yellow Queen', and 'Flamenco'. These are overwintered and planted out in March/April. The main batch of root cuttings now start and carry on for the next 2 months. These are *Phlox paniculata* cultivars such as 'Eva Cullum', 'Franz Schubert', and 'White Admiral'. *Anchusa* and *Verbascum* come next. These can either be put into the ground in bunches held together by an elastic band (which is not so tight as to cause root damage), or singly in rows.

In January root cuttings are continued which include: *Anemone* × *hybrida,* with root pieces scattered, as well as *Echinacea purpurea* 'R. Bloom', *Limonium latifolium* 'Violetta', *Geranium sanguineum,* and *Symphytum* 'Rubrum'.

In February: The bergenias are propagated from 2 and 3-year old plants; the stem sections are sliced into 1 in. lengths, which are pressed into compost and when they shoot they are further sliced and then potted. *Sedum* 'Autumn Joy' and *Sedum* 'Ruby Glow', and *Veronica* can all be put under polythene covers. These are all made as heel cuttings.

In March *Achillea* 'Moonshine' is propagated—also *Achillea filipendulina* 'Goldplate', and *Achillea filipendulina* 'Coronation Gold'. Delphiniums are now pushing up quickly. We only do *Delphinium* × *belladonna* cultivars from heel cuttings. *Aster novae-angliae* 'Alma Potschke' cuttings are best taken as heel cuttings as

they are quite difficult to split. *Salvia* × *superba* cultivars are coming now—'Lye End', 'Indigo', and 'East Freisland'.

By April *Chrysanthemum* × *maximum* 'Snowcap' can be split in the field. We also take cuttings now to provide potting plants and plants for next year's field propagation. Campanulas have soft growth. *C. lactiflora* 'Pouffe', *C. lactiflora* 'White Pouffe' and scabius can all be done now. Tip cuttings are also started in April, *Gypsophila paniculata* 'Compacta Plena', and *Monarda didyma* 'Cambridge Scarlet' can be started by division or tip cuttings. Large numbers of dwarf asters are propagated in April also to increase our autumn-flowering garden centre trade.

In May: *Euphorbia griffithii* 'Fireglow' will come into its own. This is a difficult plant to propagate, since until you have over-wintered the cuttings you cannot guarantee that the plants will ever establish and grow away. Lamiums go into the frame in May and are very quick to start, Lythrums are started from scratch each year using tip cuttings in the frame or in mist. For Sedum 'Autumn Joy', and *Sedum* 'Ruby Glow', the plants from the cold frames will go as open ground and the tips will go potted as container plants in June and July.

In June tip cuttings are at the peak period. Those we use are *Veronica spicata* cultivars, *Artemesia* 'Powis Castle', and *Phygelius capensis* 'Yellow Trumpet'. The frame yard is now basically cleared; open ground planting has now finished and sterilization of the frames takes place to be ready for the new season.

July and August are for seed propagation and staff starts pricking out or lining out seedlings. Cutting propagation of one or two plants must be done at this time, e.g. *Papaver* 'Fireball' from root cuttings. This is so rapid that cuttings can be taken in July and plants sold in 9 cm pots in September. *Heuchera* cultivars and Vinca propagation can also be done in August.

SEED PROPAGATION:

A considerable number of plants are grown from seed, some of which we collect ourselves and the remainder we buy through seed catalogues. We try to sow at the correct times rather than worrying about dormancy problems. The season starts with collecting *Helleborus* seeds which are sown in July in the open ground. Germination takes place about 6 months later. The seedling could then be planted the following June or July with plants for sale in September onwards.

Our programme for seed includes both open ground and box sowings.

Phase 1: December or January with box sowing. This provides work at this time and is useful for seeds that require good frost treatments, e.g. gentians and primulas. Seed germination takes place in March and April.

Phase 2 comes next and is more specific. *Alchemilla mollis* seed requires as much frost treatment as possible, but it is still difficult to germinate. *Aruncus sylvester*, *Heuchera* × *brizoides* Bressingham hybrids, *Caltha paulstris* 'Alba', *Geranium armenum*, *Germanium sanquineum*, *Chelone obligua*, *Polygonum milletii*, *Rodgersia*, *Rudbeckia fulgida* 'Goldsturm' and *Knautia macedonica* [syn. *Scabiosa rumelica*] seed are sown at this time.

Phase 3 usually comes at the end of March/early April. This is a major part of the seed propagation program. *Campanula*, *Delphinium*, *Doronicum*, *Lobellia*, *Malva alcea* var. *fastigata*, *Nepeta nervosa*, *Phygelius capensis* and *Meconopsis betonicifolia* [syn. M. *baileyii*] seeds can be sown now. They all seem to require humidity and warmth to germinate effectively.

Phase 4 takes place at the end of May/June. Seeds sown are of cultivars that react very quickly, such as *Gaillardia*, *Digitalis*, as well as some second batches of *Heuchera*.

For *open ground sowings*: We use autumn sterilized soil with Basamid. The temperature of the soil is high enough by the end of March/early April for sowings to take place. We sow in 3 groups:

1) *Mature plants, less than one year from seed*: *Aquilegia*, *Euphorbia*, *Salvia*, *Eryngium*, *Oenothera missourensis*. These plants are saleable by the following September.

2) *One year from seed*: *Kniphofia*, *Thalictrum*, *Ancanthus*. The seedlings are planted out after 1 year.

3) *Two-years from seed*: Germination is erratic or the plant seedlings are not big enough to handle before two years from planting: *Eryngium bourgatii*, *Paeonia moksewitchii*, *Agapanthus* hybrid seedlings, *Ophiopogon planiscapus* 'Arabicus', *Dictamus albus* seeds are sown in drills, 1½ in. deep and scattered in the rows by hand. Beds are on sterilized land, but they still need hoeing. Plants are destined for container sales or open ground planting.

The container area of the herbaceous plant department is about 5 acres having five permanent staff which handles 950,000 plants. Of these 750,000 are in 9 cm pots, 100,000 in 2 litre pots, plus a new range this year of 1 litre pots; 100,000 of these good quality perennials are for garden centre sales, specifically.

GARDEN FERNS WORTH GROWING

DONAL SYNNOTT

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Glasnevin, Dublin 9, Ireland

The time may be right for an expansion of the pitifully small number of ferns in popular use. A search of the retail outlets for plants in the Dublin area, including garden centres, florists, and supermarkets, would produce the following short list:

House plants:

Adiantum capillus-veneris (common maidenhair fern)
Nephrolepis exalta (sword-fern and the cultivar known as Boston fern).
Asplenium nidus (bird's-nest fern)
Pellaea rotundifolia (button fern)
Cyrtomium falcatum (Japanese holly-fern)
Plus one or two unnamed exotics.

Hardy ferns:

Athyrium filix-femina (lady-fern)
Dryopteris affinis (scaly male-fern)—probably a cristate cultivar.
Polystichum setiferum var. *acutilobum* (soft shield-fern).
And occasionally *Matteuccia struthiopteris* (shuttlecock fern) and *Blechnum magellanicum [syn. B. tabulare]*.

All of this is indicative of a poor state of affairs in regard to fern gardening in Ireland. Since it should be the responsibility of Botanic Gardens to provide headlines and ideas for improvement, the fern garden at Glasnevin has been reorganised and is in the process of expansion. The site, a steep bank facing north, is perhaps not the most suitable for ferns but it had one great advantage—it was available.

The collection includes native species and varieties and some exotics. Since the original plantings two years ago, the beds have been devastated by two happenings: all of the species and varieties of *Polystichum*, except *Polystichum braunii*, have succumbed to an unknown or untraced disorder and of the forty fern varieties planted originally, fourteen disappeared without trace within three weeks and three others have since joined their ranks, one as late as June, 1986! This is a hopeful sign. If there is someone around prepared to steal ferns, then they must be becoming desirable plants again and the group as a whole may be staging a comeback.

The remarkable interest in fern growing which existed in the Mid-Victorian era and which is known to historians as the Victorian Fern Craze, has been well documented, most recently and comprehensively by Allen (1). The popularity of ferns from about 1840 to

the end of the century was due to a number of factors, some of which can be identified or at least suggested: in Victorian society, colour and gaiety in outward expression were deliberately subdued so that green plants such as ferns, ivy, and aspidistra were suited to the modes of the times; the urbanisation of Britain following the Industrial Revolution separated people physically from the countryside, while the Romantic movement in poetry and art regarded nature and the countryside as the ideal surroundings for man; fern growing presented a challenge—the production of beautiful plants from tiny spores was a mystery and a delight; the invention of the closed glass case for transporting and keeping plants meant that ferns could be kept in hostile urban environments; any form of greenery which provided an alternative to the aspidistra must have been visually stimulating and welcomed with open arms.

All of this was good for business. Although the Fern Craze owed its origins and its excesses to the enthusiasm of amateur growers and collectors, it had spin-off effects for nurserymen, gardening supply shops, publishers, and writers of gardening books, and professional horticulturists and botanists.

In the early years it seems that emphasis was placed on foreign exotics, especially from Australia and New Zealand. A certain John Reilly of Papplewick, near Nottingham, had nearly 300 species in cultivation at the time of his death in 1846. For nearly a decade before that date the fashion for ferns had been gathering momentum. The number of ferns and fern spores were steadily increasing in the catalogues. The Wardian case had made its appearance. After a walk in the Welsh mountains, Edward Newman had suddenly succumbed to what he described as "that lasting and incurable disease, the Fern Fever".

Like St. Paul, Newman came late to his vocation, but he came to it with a vigour and conviction that was to have a lasting and important influence on the fern trade. Newman became friends with Nathaniel Ward, who had developed the closed glass case for growing and transporting delicate plants, and between them they transformed what was a hobby into a craze. Like most devotees of fringe pursuits, Newman exaggerated the popularity of fern growing to an absurd extend. In 1840 he wrote, "The cultivation of ferns is becoming a fashional pursuit, almost everyone possessing good taste has made, more or less successfully, an attempt to rear this tribe of plants".

A History of British Ferns (4) was a most influential book and spread the fever from the growing group of fern gardeners to the steadily growing ranks of field botanists. Coupled with the gardening fever, there was now a parallel and often overlapping group of those who collected ferns for their botanical interest. This brought a greater precision to fern nomenclature and switched the focus of attention from imported to native plants.

A second phase of the fern craze, the search for varieties of native ferns led to the kinds of excesses which were to undermine the whole movement. Overcollecting of rare species from well known sites; raising, describing, and naming of every abnormality or monstrosity raised from spores of ferns collected in the wild, discredited the enthusiasts in the botanical world. After a high point in the 1860's the fern craze waned but left a legacy of good and bad garden plants. Finally World War I, which changed the world, dealt a final blow to the group of plants which belonged with Wordsworth and Romanticism, Tintern Abbey, and the Lakes of Killarney gentleness and a belief in the hierarchical order in nature and in the world of men. The fern group, which had once dominated the vegetation of the earth and had briefly reigned supreme in the garden were now relegated to a role of botanical and horticultural curiosity. We are fortunate that, by a combination of accident and devotion, many good plants have survived, from which the cultivation of ferns may again expand.

Just as the horticulturists and botanists had combined to promote the fern craze so they joined forces in bringing it to an end. The botanists proceeded to annihilate the rarer species in their known habitats. Of the Killarney fern at Torc Waterfall Newman says, "I have stood amid the roar of waters gazing on hundreds of the dark green fronds of this fern as they waved to and fro in the agitated air, and sparkled with myriads of sun-lit drops. . . . I am told that this scene is to be gazed on no more, that all its beauties have been ruthlessly destroyed". Newman was perhaps more concerned with conveying the dramatic essence than the literal truth but the Killarney fern is certainly gone from Torc Waterfall.

Over wide areas of the trade standards of taste completely collapsed (1). All kinds of abnormality or monstrosity, whether grown from spores or dug out of the wild, were named and sold for inflated prices to a gullible public. Most of these were fit only for the rubbish heap (3). Allen adds, "(the trade) . . . by acting irresponsibly, helped to break the fashion that had brought it adventitous profit . . . and the connoisseurs increasingly abandoned their hobby in disgust".

At the peak of the trade the specialist nurseries had large selections to offer: Robert Sim of Foots Cray in Kent had 818 species and varieties in his catalogue; the 1861 catalogue of Stansfields offered over sixty varieties of hart's-tongue alone, priced from one shilling to a guinea for a few exclusives.

Fern enthusiasts in Ireland and Britain are catered for by the British Pteridological Society. The society issues a Journal, a Bulletin, and occasional special publications. The latest of the special publications is *A Guide to Hardy Ferns* by Richard Rush (6). In this, some 581 species of varying degrees of hardiness and attractiveness are listed. Many are only tolerably hardy in the milder areas

but still a considerable number would do well in the average garden. There is certainly a good basis in this list for experimentation and expansion. From the dozen or so species now readily available it should be possible to increase our garden fern population by dozens if not by hundreds of species.

Plants can be sold to the enthusiast if they have an interesting story or name or come from some exotic place; the supermarket plant must have visual appeal if it is to move off the shelf. No amount of storytelling will convince the casual shopper to have an otherwise boring plant taking up space.

Clues to what might be suitable subjects for mass production are to be found in the literature. J. W. Dyce describes *Woodwardia radicans* 'Plumosum McCormack' as "of outstanding beauty and refinement", a better starting point than *Woodwardia virginica* which "faded away when planted out in a seemingly suitable site in a new garden" (6). *Dryopteris wallichiana* "a handsome fern . . . hairy black croziers—charmingly sinister—are a bonus" would seem to be a better bet than *Grammitis billardieri* "difficult to keep going . . . in Australia" (6). *Paesia scaberula* "abundant throughout New Zealand, often growing in full sun on poor soils . . . could well be invasive . . . very attractive" is more likely to take on than *Cryptogramma crispa* "a fanatical lime hater" (5).

For the future it would be nice to see the better and more lasting varieties of native species popularised. Raising new varieties of native species must be accompanied by a ruthlessness not normally associated with the gentle profession of horticulture; much of it will be going over the same ground as the Victorians, who did a superb job of exploring the possibilities of the native species. Many of the best forms are still in cultivation. One way forward would be to promote these and to look for new foreign species which will stand up to the rigours of our climate or the uncertainty of the supermarket shelf.

Of the 12,000 species of ferns in the world, Richard Rush has listed some 581 which are hardy or semi-hardy in the British Isles. More will be found. John Reilly of Papplewick was able to grow nearly three hundred species one and a half centuries ago. What man has done man can do. If it were possible to produce good lively specimens of only a fraction of these then the average gardener might be persuaded to increase his fern holdings from one or two varieties by a few hundred percent, while still retaining some space for a pink oxalis outside or a mother-in-law's-tongue in the kitchen window.

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THE NEED FOR GRASSES AND BAMBOOS

JOHN JOE COSTIN

Costin's Nursery,
Portgloriam, Kilcock,
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The quintessential Japanese Garden was created by Buddhist monks. It resulted from their need to have an environment which aided rather than distracted them in their meditation. The garden they designed provided the ambience of timelessness with no evidence of seasonal change. These were composed of evergreens, rocks, and water. They are classically beautiful gardens. Since the early 1960s landscape design has been abysmally dull. The raison d'être of these designs is that they had to be managed with residual herbicides. Plant selection was limited to those resistant to simazine. We have now, as a monument to the abandonment of good design skills, the incongruous conifer and heather gardens suffocating in soils too sumptuous and rich for plants of such humble origin. Alternatively for amenity schemes we have pastures of *Potentilla*, carpets of *Cotoneaster*, and barriers of *Berberis*.

Designs such as these based exclusively on woody plants are stiff and unbending, lack movement, and do not have the lovely textural changes which can be effected through the use of a wider range of plants.

Grasses offer the perfect foil to the heavy rounded outline of shrubs and other plants. Grasses were seldom used in the great herbaceous borders. The accent was on flower colour, à la Gertrude Jekyll. Since the war the emphasis has been greater than ever on flowers, with breeding directed towards creating bigger and larger, and brighter and gaudier flowers—begonias and roses being just two examples.

Thankfully today there is increasing awareness of the value of plants versus just flamboyant flowers and so, as a result, grasses have come very much into their own. The more aesthetic landscape designers use them freely to add that different texture line and lightness to general planting schemes. There are many plants besides grasses that have a grassy effect, such as *Acorus*, *Crocosmia*,

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Dierama, Hemerocallis, Iris, Libertia, Liriope, Ophiopogon, Phormium, Sisyrinchium, and Yucca. In this paper I deal only with the true grasses, sedges, and bamboos suitable for the small garden.

The larger grasses in moist ground emphasize, by way of contrast, the enormous leaves of *Gunnera, Peltiphyllum, Rheum,* and *Rodgersia*. However, with the size of our domestic gardens ever decreasing the smaller grasses are ideal modern plants for such locations.

Grasses can be divided into giants—over 1.5., those over 0.5m. and those less than 0.5 of a metre. The tallest plants include *Arundo donax, Cortaderia, Miscanthus,* and *Stipa gigantea*. We grow four cultivars of *Cortaderia selloana:* 'Gold Band', 'Pumila', 'Rendatleri', and 'Sunningdale Silver'. *Cortaderia fulvida* is the most graceful of all the pampas grasses, flowering in June. *Arundo donax* makes a giant plant as does *Miscanthus sacchariflorus*—3m. or more.

Smaller growing and more graceful grasses are *Miscanathus sinensis* 'Gracillimus' and the free-flowering 'Silver Feather'. The cultivar 'Zebrinus' has lovely horizontal markings on the stems.

MEDIUM SIZE GRASSES AND GRASS-LIKE PLANTS

Carex buchananii. This produces hundreds of rounded shiny, bright, reddish brown stems in a clump that is fountain shaped and does not spread. A unique colour among grasses. 60cm.

Chionochloa flavicans. (60cm × 60cm) A miniature pampas grass, in essence, with the same flower spikes produced in June.

Pennisetum alopecuroides and *P. alopecuroides* 'Woodside'. These are very free flowering grasses producing distinctive indigo bottle brush heads in September–October.

Phalaris arundinacea var. *picta* is a marvelous brightly variegated grass but is very invasive. It can be grown very successfully in a sunken barrel.

SMALL-SIZED GRASSES AND GRASS-LIKE PLANTS

Most of the grasses we grow are under 50cm in height and so are ideal small garden plants. The important ones are:

Acorus gramineus 'Variegatus' (20cm), is densely tufted, very hardy, small, brightly variegated and evergreen, but is not really a grass.

Alopecurus pratensis 'Aureus' (45cm). Leaves are entirely gold, making a vivid coloured clump. Hardy, and easy to grow in all but the driest soils.

Arrhenatherum elatius bulbosum 'Variegatum' (30cm). One of the brightest white striped grasses. Easy to suit in any soil, but has a spreading root system.

Carex morrowii 'Evergold' (30cm). This has been our best seller.

It is evergreen, brightly variegated and mushroom shaped. Very hardy.

Carex ornithopoda 'Variegata' is a much smaller grass at 15cm, forming a neat mounded tuft.

Carex siderostricta 'Variegata' has very broad leaves with variegated stripes, making a good feature plant at the front of the border.

Carex stricta 'Aurea' (30cm). A dramatic grass because of its wonderful colour. Ideal for sunny moist spots. Hardy and easy to grow and does not spread.

Dactylis glomerata 'Variegata', 25cm. in height with beautifully variegated foliage, tufted growth, and roots that do not spread. Thrives in dry, well-drained soils.

Festuca scoparia. This is a miniature, 10cm. in height. It produces a mat of bright green evergreen foliage. Ideal as a contrast plant at the front of the border.

Hakonechloa macra 'Aureola', 30cm. in height. A gorgeous multi-coloured grass from Japan which forms a neat clump and grows best in light shade.

Holcus mollis 'Variegatus'. This is another lovely brightly variegated dwarf grass which is 15cm. in height. Hardy and easy to grow in any soil.

Milium effusum 'Aureum', 30 cm. Keeps its clear golden foliage throughout the year, growing best in light shade and damp conditions.

Molinia caerulea 'Variegata'. This is one of the most graceful of all grasses, forming a neat vase shaped clump. Its airy and light habit make it an ideal contrast to the heavier round outlines of surrounding plants.

Stipa arundinacea, 45cm. An evergreen mass of matching foliage produces lovely 1m. tall flower spikes and has very good autumn colour. Grows best in heavy soils that do not dry out.

We have in stock approximately another 20 different grasses, but do not have these available in commercial quantities.

BAMBOOS

We supply garden centres exclusively, so we primarily select plants suitable for this market. The two most popular bamboos are *Arundinaria variegata* [syn. *Pleioblastus fortunei*], and *Arundinaria viridistriata* [syn. *Pleioblastus viridistriatus*]. Both are dwarf (1.3m.) and form neat clumps, variegated white and gold, respectively. Brightest in full sunshine. Both make excellent tub plants.

Sasa mirrezuzume, (30cm) in height. A very recent introduction from Japan. Light green foliage forms a dense carpet.

Sasa veitchii. (1.2m). This plant is invasive, but it is a very popular bamboo. The leaves are extra broad and the margins blanch

which gives a variegated effect. Ideal for large tubs.

Shibataea kumasasa. (0.8m). A very hardy and wind-resistent bamboo. Forms a tight, leafy clump. Does not spread. It is a very elegant dwarf bamboo, distinct in appearance from all others, with broad stubby leaves.

We also produce *Arundinaria japonica* 'Murielae', *A. nitida*, and the tiny but invasive *Arundinaria pygmaea*.

PROPAGATION

All our plants are grown from division, none from seed, so far. The evergreen grasses and sedges are divided in March, but the deciduous kinds and the bamboo are not touched until May or June when growth has commenced. Other plants are divided and the divisions potted into a peat-only compost, coarse grade, with 2-year Osmocote. The 9cm. pots in Empot carriers are set on a capillary bed in the glasshouse. Once established and growing well most of the grasses are moved and over-wintered outdoors on a well drained capillary bed.

In the following May, these plants are repotted into a 2 or 3 litre rigid pot in a coarse grade peat compost and grown on capillary beds.

The larger grasses, particularly the *Miscanthus*, are divided last. These are started in a 1 litre pot and then moved to a 3 or 4 litre pot. In this size container they make 3m growth in the season. Latterly, we have stopped making divisions of the named forms of *Cortaderia* as we find it is easier to buy micro-propagated plants which establish readily and go on to produce a very uniform crop.

All our capillary beds have a very positive winter drainage system and we feel that this is a important contributory factor to over-wintering grasses in their first year.

Most grasses are retailed in small pots 9cm or less. These are very difficult to manage and losses result. We grow all our plants in a minimum 2 litre pot size, which gives the retailer a much better product to manage and sell.

PLANTS IN SOUTH KOREA: MY IMPRESSIONS

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I visited South Korea in April/May, 1984, at the invitation of Mr. Ferris Miller, born an American but who adopted Korean citizenship. He, I understand, works in the Korean Stock Exchange during the week but at weekends and whenever else he can, travels about 100 km south to a small village called Chollipo on the Yellow Sea coast. Here he has his arboretum.

He has collected many species of plants from many parts of the world. Naturally, with China and Japan on either side of South Korea there is a predominance of plants from that area.

My wife and I did get into the hills of the area and we also went south to Kwanju and later flew to the southern island of Cheju and climbed nearly to the top of Mount Halla. Listed below are some interesting plants that we saw[1]:

Aesculus species

Carpinus coreana. I thought this small tree with its bushy habit a winner for landscape work.

Cedrela sinensis 'Flamingo'—when this shrub comes into growth in the early spring the glowing pink young growth is really very, very pretty.

Cercis chinensis—a much richer flower colour than *Cercis siliquastrum* and the flowers more densely packed.

Cercis chinensis 'Alba'—a pure white form.

Daphne genkwa—not a plant to put on a big display in our part of the world, but how beautiful it is in its native habitat with its beautiful lilac-blue flowers.

Edgeworthia papyifera—another plant that excels in its own climate with its yellow 'scented' daphne-like flowers.

Epimedium species—large lilac-blue flowers.

Euonymus alata var. *macrophylla* I collected seed from this very wide winged barked euonymus but, unfortunately, they did not germinate.

Euonymus japonica 'Chollipo'—a selection made at the arboretum with gold-edged leaves and an upright habit.

Magnolia 'Maharanee'—a pure white.

Magnolia × *soulangiana* 'Coates', a very good form with deep reddish-purple flowers.

Magnolia 'Woodsman'—lovely yellow flowers. (Magnolias are Ferris Miller's first love and he has a very good collection).

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[1] Mr. Catt showed slides of all these plants (Ed. Note).

Weigela koriana—the flowers, turning as they do from yellow to orange to red, make this plant a winner for me.

The following species were also observed in South Korea:

Abies koreana,

Ginkgo biloba—freshly planted and heavily pruned,

Hepatica asiatica,—in damp shady area,

Juniperus species—clipped "paddle" fashion,

Magnolia liliiflora—A very rich purple,

Paeonia species—a beautiful tree type,

Pinus bungeana—in a school playground,

Pinus densiflora—this pine and *Pinus thunbergiana* are the predominant trees and sometimes one sees hybrids between the two,

Primula sieboldii—growing in damp soil,

Prunus glandulosa 'Sinensis',

Pulsatilla species—with brown-red flowers—on a dry area,

Rhododendron poukhanense—covers whole hillsides beneath the pines,

Rhododendron species—a dwarf azalea above the tree line on Mount Halla,

Zelkova serrata—a stock plant for bonsai.

PROPAGATING *RHODODENDRON YAKUSHIMANUM* BY CUTTING-GRAFTS

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Some cultivars are particular difficult to root from cuttings and we therefore have to look at alternative methods of propagation. This paper will discuss the "cutting-graft technique" which we have successfully used for rhododendrons.

The species with which we have done most work is *Rhododendron yakusimanum,* which forms a compact, dome-shaped bush up to about 1.2 metre high and the same across. The young growths are silvery, and the mature leaves are dark green above with a brown indumentum underneath. It flowers prolifically in a compact truss, rose-coloured in bud, opening pink, and maturing to white. This species is only found in the wild on the wet and windy mountains of Yakushima Island, Japan. It was introduced to the United Kingdom in 1934 and has become a very desirable plant.

Our first attempts at propagation were from cuttings. Cuttings were prepared in the usual way, wounded, and treated with a hormone rooting powder and then stuck in seed trays containing a peat/sand mixture. It was unusual to find roots being produced, although even after 12 months the cuttings were in good condition. The few cuttings which rooted tended to grow very slowly. This led to the consideration of other methods of propagation, one of which is the cutting-graft technique.

A *graft* is made when a piece of living tissue (a *scion*) is transplanted into a slit on another plant (the *stock*) so that the scion can get sap from the stock and a union is eventually produced.

A *cutting-graft* is exactly what it says. A scion is grafted onto an unrooted cutting which is then stuck as usual into compost in a tray. This is a different method from that used to graft a scion onto a root.

METHODS AND MATERIALS

The materials required are understocks, scions, grafting tape, and seed trays filled with compost. In addition a sharp knife is required.

The understocks used can be of any *Rhododendron* which is compatible with *R. yakusimanum* and which is easy to root. Cultivars found to be suitable are 'Cunningham's White', 'Christmas Cheer', and *R. ponticum*. There may be a preference to use *R. ponticum* because it is more readily available and the variety diameter of the stock material makes it easy to match with the scions.

Scion material is in short supply and therefore every piece of the current year's growth is used. The ideal size for understock and

scion is pencil thickness.

A piece of understock material about four in. long is selected and all the leaves, apart from two at the top, are removed. If the top of the shoot is used, the apex (or growing tip) is removed. Any buds on the stem of the cutting below the two leaves are now removed with a sharp knife. This is done by making a small angled cut above and below the bud in a v-shape, with the result that the bud drops away. The base of the cutting is then wounded in the normal way.

The top of the cutting is then prepared to accept the scion. A side veneer graft is normally used and the first step is to make an incision about 1-in. long in the side of the cutting, starting immediately above the lower of the two leaves at a 20° angle. A second cut is then made, starting ⅓ to ½ in. higher up the stem at a 15° angle to meet the first cut at its bottom end. A very thin wedge of the stock is therefore removed, exposing as much cambium as possible and making it easy to insert the scion.

A suitable scion about the same thickness as the understock is then selected. Two cuts are made at the base of the scion of the same length as the cuts on the understock. The cuts are made at slightly greater angles than on the understock so as to form a tapered wedge when compared to the understock.

The scion is then inserted into the understock in such a position that the cambium layers of the stock and the scion are in contact. The graft is then tied to hold the two parts together. Tape is used to wrap around the stem of the understock, care being taken to avoid tying too tightly and leaving small gaps between each wrap around the stem. It is also possible to use the saddle or inverted saddle graft.

To finish the preparation of the cutting-graft, the leaves of either the stock or scion may be reduced in size to decrease transpiration and overcrowding in the seed trays. The cutting-graft is now inserted in a seed tray filled with a mixture made up of three parts sand and one part peat. A rooting hormone is used, made up of equal parts of Seradix No. 3 and Captan; 40 cuttings are inserted in each tray.

The seed trays are placed on the propagation bench with bottom heat at about 18°C. They are only slightly watered-in and then covered with thin gauge polythene making sure the polythene goes down the side of the trays so that high humidity is maintained. The polythene is removed at least every other day when trays are checked for drying-out and any debris is removed. The propagation bench is watered once a week to make sure that high humidity is maintained under the polythene. Care has to be taken to shade the cuttings in sunny weather to avoid scorching. Pests and diseases are controlled by our routine glasshouse spraying programme and no special problems are experienced.

During the last two years propagation has been carried out in

the fog unit, thereby eliminating the need to use polythene. The amount of work involved in looking after the cuttings is then much reduced and results have been very satisfactory.

When the cuttings are rooted they are weaned prior to potting. After emptying the cutting tray, the two leaves and buds which were left at the top of the cutting are removed. The two cuts which were made on the stock are painted with Arbrex, and the tie taken off. Any buds which may have been left when the cutting was made, or which have subsequently formed, are also cut away. The cuttings are then potted using a lime-free compost or they can be planted into beds.

Depending on the season, grafting is done either during September or in early October. Cuttings are rooted by about the end of February, although they are not potted until July, which fits in with our programme on the nursery.

Compared to grafting onto *R. ponricum* seedlings as understocks, the main disadvantages of the cutting-graft method are that it is a little slower to produce a finished plant, and that sometimes the understock does not root for some reason.

The main advantages are that less space is required for propagation, it is a very clean technique, and the cuttings are easy to handle. In addition, there is a larger choice of understock material and timing is not quite so critical when compared to using seedlings as the understock.

CONCLUSIONS

So long as the graft is executed carefully and the cambium layers are lined-up properly, there are very few problems with this method. Because *Rhododendron ponticum* roots easily, it has proved to be a useful technique, with success rates in excess of 70%.

This method can also be used to propagate other *Rhododendron* cultivars and for *Camellia reticulata* cultivars, which are difficult to root.

DIRECT STICKING EVERGREEN AZALEA CUTTINGS

ANDREW KELLY

Bord na Mona, Lullymore Nurseries,
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A prime objective in plant production must be to minimize growth checks. Conventional tray propagation and subsequent root disturbance before potting involves a major check to growth. Direct sticking of cuttings into a pot containing fertilized compost ensures that as the cutting produces roots it grows away without disturbance. It is commonly argued that fertilized compost retards rooting. Our experience has shown that rooting evergreen azaleas in pots of fertilized compost is feasible. Subsequent growth is superior to that obtained by using more conventional systems.

In 1982 and 1983, we incorporated nutrients in our rooting composts on a trial basis. We had very poor results. At the I.P.P.S. conference in 1983, Tacchi (3) and Down (2) gave papers which indicated that nutrient incorporation in propagation composts was successful for easily produced hardy nursery stock. A picture of *Rhododendron* 'Fashion' in a paper by Carney and Whitcomb (1) convinced us that we should try again.

We conducted two trials, one in a glasshouse, the other in a walk-in 14 ft poly tunnel. Cuttings were inserted in 7cm pots in a series of six composts. In one trial, the pots were covered with 80g polythene draped over hoops in a heated glasshouse propagation bench. In the second trial pots were covered with 80g polythene draped over hoops in a poly tunnel covered with 600g "milky" polythene. Four rates of slow-release nutrients were tried. Carney and Whitcomb mentioned very high rates of nutrients. This influenced our choice of rates (see Table 1).

Table 1. Rates of fertilizer used in the rooting medium

	Kg per cubic metre		
Compost	Osmocote 18:11:10	Magnesium limestone	Micromax (micronutrients)
1	0	2.5	0.47
2	1.5	2.5	0.47
3	3.0	2.5	0.47
4	4.5	2.5	0.47
5	6.0	2.5	0.47
6	0	0	0

The cuttings were inserted on May 25th, 1984. The bulk constituents of the compost were two parts medium grade moss peat and one part granitic sand. All cuttings were treated with Seradix 3 rooting hormone.

The following observations were made:

1. Increasing fertilizer levels led to a reduction in survival.
2. Incorporation of trace elements and lime alone did not reduce rooting.
3. Rooting became more erratic as fertilizer level increased.
4. The more controlled atmosphere of the glasshouse gave more even results and higher percentage survival.
5. Although plants may have rooted in composts containing high nutrients, we did not record them as survivors unless they were fit for potting on.

Table 2. Percentage survival of three evergreen azaleas cultivars to potting on, using various composts.

	'Florida'		'Addy Wery'		'Vuyk's Rosy Red'		Average
Compost	(a)	(b)	(a)	(b)	(a)	(b)	
1	95%	100%	95%	80%	81%	100%	92%
2	96	6	96	96	90	0	64
3	96	45	78	0	71	38	55
4	83	38	11	75	30	81	53
5	20	0	0	0	0	0	3
6	100	100	100	93	100	73	94
Average	81	48	63	57	62	49	60

a= glasshouse b= polytunnel

The rooted cuttings were subsequently potted on into two litre pots. In 1985, the plants which had been rooted with slow-release fertilizer grew away faster than those without fertilizer. The increase in growth did not vary significantly where increased rates of slow-release fertilizer had been used during propagation.

Our experience to date suggests that maximum benefit is derived from this method if the cuttings root quickly. Conventional propagation will accommodate some deviation from good procedure, but direct sticking demands strict adherance to good propagation procedure.

The benefit from direct sticking and the use of fertilizer was evident in subsequent plant development. A reduction of up to one year in the production cycle was achieved when compared with tray propagation without fertilizers.

In 1985, 10,000 cuttings were inserted using Mix 2 above (see Table 1). Eighty percent of these cuttings survived to potting on.

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CAMELLIA PROPAGATION

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INTRODUCTION

The demand for camellias has increased over recent years as its potential as a garden/patio/conservatory plant has been recognised by a wider sector of the public. At the same time the traditional sale by length of often single stemmed plants has been replaced by a demand for younger well branched/budded material. Production of this type of plant has required close attention to detail at all stages of growth and a recognition that quality and type of cutting, together with their treatment both during and after propagation, has a major influence on establishment and subsequent growth. This paper reviews the various factors influencing the successful propagation of quality camellias which have been identified during our extensive experimental programme on camellia production at Efford EHS, which culminated in recommendations for an accelerated production schedule (1).

SOURCE OF CUTTING MATERIAL

A source of quality, well-graded cutting material provides the key to a successful propagation programme.

Growing plants: A major source of propagation material has traditionally been from the growing crop when stopped back in the autumn. However, material from this source is often variable and limits the scope for stopping during the season to improve branching.

Stock plants: Ideally cuttings should be obtained from stock plants either container-grown specifically for this purpose or from a stockbed area. This provides the opportunity for manipulation of growth to produce flushes of quality material and selection of graded cuttings. At Efford an area of stock camellias has been planted and has provided information on plant management to achieve this objective.

In the south of England stock plants can be grown outdoors but

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chlorosis and "bleaching" of foliage together with hardening of growth can occur from too high light intensities (sunscald). Use of a 50% shade structure over the plants has eliminated the adverse affects of sunscald and has produced a marked improvement in growth and quality of cuttings. Further north greater stock protection will be required, either under plastic film or glasshouse structures.

Provided camellias are planted on a soil type suitable for calcifuge plants (pH range 5 to 5.6) then the fertilizer rates shown in Table 1 have given excellent growth under Efford conditions.

Leaflet 642 "Nutrition of Field-Grown Nursery Stock" gives fuller details.

Table 1. Recommended fertilizers for stock planted in the field (kg/ha).

	Fertilizers required before planting					Fertilizers required as annual top dressings in the first few years			
	Index before planting					Index before planting			
	0	1	2	3	over 3	0	1	2	over 2
Nitrogen[1] (N)	50	—	—	—	—	50	—	—	—
Phosphate (P_2O_5)	100	75	50	25	Nil	50	25	Nil	Nil
Potash (K_2O)	200	150	100	50	Nil	100	50	25	Nil
Magnesium[2] (Mg)	75	50	25	Nil	Nil	25	Nil	Nil	Nil

[1]Low pH maintained by use of ammonium nitrate (34% N).
[2]Similarly, Kieserite used as source of magnesium in preference to Mg-lime.

Regular pruning is important to maintain "juvenility" and produce uniform flushes of cuttings. With older plants (5 to 10 years) a "renewal pruning" is practised. In early spring the older third-year wood is cut hard back. The resulting growth from latent buds is extremely vigorous and unsuitable as cuttings. However, when these shoots are cut back by half in the second year a good flush of cuttings is produced prior to its removal in the third year.

Good hygiene in the stock area is also essential to ensure only healthy cuttings are taken on into propagation. A previous paper (2) outlined problems encountered from the disease, *Monochaetia karstenii* which, if allowed to build up unchecked, caused severe leaf drop and death of cuttings and young plants. Stock plants themselves are in the main unaffected by this disease but provide a major source of infection, spores overwintering on dead flowers, in stem lesions, and on damaged leaves. Regular stock inspection and removal of dead, diseased, or damaged material is important together with a routine fungicide programme with an application prior to taking cuttings. In trials, a formulation of prochloraz/manganese complex (Octave) has given reasonable control of the disease.

PROPAGATION

Type of Cutting: Ideally terminal cuttings should be used since they produce plants which branch more freely and grow away faster than those from leaf bud cuttings. The latter should only be used if material is scarce since plants from these cuttings may well take an extra year to produce as well as having poorer basal branching.

Trimming of leaves to increase density during propagation needs to be avoided if at all possible since the cut provides entry for the wound pathogen, *Monochaetia karstenii*. Some cultivars are more susceptible to the disease than others (i.e. Donation, Henry Turnbull) and, if space is limiting, some selection as to which cuttings are less likely to become infected if trimmed is possible.

Time of Taking Cuttings: Two main flushes of growth are produced each season, the first in April-June, followed by a second in late July-August, depending on site and season. This enables two batches of cuttings to be taken:

(a) July/August as the first flush of growth ripens.

(b) November-January from the second flush.

The summer strike is particularly suitable for the accelerated schedule or production of liners since cuttings can be potted during November into 70 to 90 mm pots which, if held under glass with a minimum of heat, become sufficiently established to pot on the following spring.

Propagation Environment: Control and handling cuttings under different environments is a subject on its own and can only be mentioned briefly in this review. Successful summer propagation can be achieved under intermittent mist, a closed mist system as developed by IHR Littlehampton, where the mist line is enclosed within a polythene tent, or under a fog environment. At Efford a pressurised air/water fog system is in operation (Macpenny) with propagation under a relatively "dry fog" produced by 10 to 25 psi water pressure/70 psi air pressure, though still maintaining a relative humidity (RH) in excess of 95%. Accurate control of RH is essential when using fog and results with an electronic humidistat (Nobel) have been good. These environments can also be used for the autumn/winter strike, but at this time of year a low plastic film tent supported just above cutting height gives excellent results, and reduces fuel costs (3). Shading during bright weather becomes particularly important for this latter system. Direct comparison of the various systems at different times of the year is still in progress.

Rooting Temperatures: Satisfactory results have been achieved for a range of cultivars with a minimum of 15°C maintained in the rooting medium. However, in some seasons a minimum of 18°C in the medium has improved the speed of rooting.

Rooting Hormones: Both powder and liquid quick-dip formulations have been trialled over several years with results somewhat variable between season and cultivar! Overall, quick-dips (lower 5 mm of stem held in solution for 5 seconds) have given as good and, in some instances, better results than the talc formulations. Trials are continuing but general guidelines are as follows:

Powders: Seradix No. 2 (3000 ppm IBA) used for summer propagation,
Seradix No. 3 (8000 ppm IBA) for winter propagation.

Quick-Dips: Both IBA (in 50% acetone) and Synergol (50% IBA, 50% NAA) have given good results. Rates of 1000 to 2000 ppm for summer propagation and 2000 to 4000 ppm for winter propagation have been used successfully, the higher concentration in each case being used for the more difficult rooting cultivars.

Rooting Media: Cuttings will root successfully in a wide range of media including mixes of peat, peat:grit, and peat:perlite. With these mixes it is important to provide a dilute liquid feed programme following weaning in order to maintain cutting quality. More recently the use of a peat:granulated pine-bark mix, together with the incorporation of a long term, slow-release fertilizer has enhanced root development and maintained cutting quality without any apparent adverse effects on rooting percentage. This improvement in cutting quality, compared with cuttings from similar mixes without nutrition, has improved establishment and early growth after potting.

The standard rooting medium in use at Efford at present comprises a 50:50 mix of medium Shamrock sphagnum peat:granulated pine-bark (Cambark fine) with a 12 to 14 month controlled release fertilizer incorporated into the mix (1.0 kg/m^3 for summer propagation under mist; 0.75 kg/m^3 for winter propagation under polythene).

Trials in progress are looking at the influence of proportion of bark in the rooting medium as related to longevity, and the rate of fertilizer incorporated. Higher rates of the 16 to 18 month fertilizers (2.0 kg/m^3) look promising.

Use of the direct sticking technique with 1 or 2 cuttings inserted in 70 mm pots in fertilized peat:bark mixes has also been successful for a range of relatively easy rooting cultivars (Tiptoe, Donation, Mattie Cole). Fuller details of nutrition during and after rooting and direct sticking results can be found in the 1985 IPPS Proceedings (4).

Liverwort has become a problem since using fertilized rooting media under high humidity environments. The problem may be

reduced or avoided by placement of fertilizer in the lower horizon of the rooting container instead of mixing throughout, and trials are in progress to compare cutting response to the two methods of incorporation. Screening chemicals for prevention of moss and liverwort during propagation is also in progress.

Pests and Diseases: Sciarid fly appears to be an increasing pest in the better aerated propagation mixes. Drenching with diazinon or fonofos (Cudgel) after rooting has now become a routine procedure.

Losses during propagation from diseases can be reduced by strict attention to hygiene reinforced by a routine fungicide programme. Mention of hygiene in the stock area, plus selection of healthy cutting material, and avoiding trimming of leaves during propagation has already been discussed. Routine inspection during propagation to remove dead leaves and cuttings is important to reduce colonisation by *Botrytis* and *Monochaetia* spores; the use of a clean water supply (mains) will reduce the risk of diseases such as *Pythium* and *Phytophthora* species.

The current fungicide programme in use during the propagation of camellias at Efford includes a rotation of benomyl (Benlate), prochloraz/manganese complex (Octave) and iprodione (Rovral) sprays at fortnightly intervals.

In conclusion, successful propagation of camellias not only includes consideration of factors influencing the rooting process but also how to obtain the best quality material to take into propagation as well as maintaining that quality after rooting. It has been demonstrated that cutting treatment during propagation can have a major influence on the quality of plants growing on and that well-graded quality rooted cuttings in active growth provide the best possible start to any production schedule.

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A COLOR PROGRAM FOR PLANTS ADAPTED TO THE U.S. SOUTHWEST

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Lone Star Growers is a container nursery with approximately 200 acres in production. We carry woody ornamentals from 1-gal., 2-gal., 5-gal. material up to 24-in. box trees. We have several specialized production areas within the nursery that set us apart from most other container operations. One is a full-scale native department, introducing and producing Southwestern and Mexican native plant material. The other is a comprehensive color department, which is the focus of this paper. I will explain the reasons Lone Star decided to include a color department from a marketing standpoint, the factors that make a color program different from container material and cultural techniques we employ to produce a quality product in the extreme climatic conditions of south Texas.

Definition of "Color". What is meant by the term "Color"? To us it includes most of the flowering annuals and perennials such as begonias, geraniums, lantanas and plumbagoes. It also includes specific crops that are not necessarily known for color but which fit into our program better than into our container production due to perishability. Santolina and ajuga are examples. We also do seasonal color specialties such as poinsettias and kalanchoe.

Marketing. What prompted a large container operation like Lone Star to start a color program? Obviously the market demands for color or blooming plants has increased dramatically and we are responding to that demand. In recent years there has been a glut of container material on the market and we have shifted our efforts into more specialty items or items that make us unique in relation to other container operations. We want to provide one-stop shopping for our customers, where they can buy 5-gal. Burford hollies as well as 4-in. pansies. A strong sales force with good market penetration already has helped make it an easy step into selling color material. As our program has evolved, we have found that color has had a very positive effect in helping sell container material. Conversely, container material has helped sell color. Very few operations can offer the diversity of plant material we have available.

Who are our customers? The majority of our customers for color are landscapers, the rest retailers, both chain stores and independents. Our product is tailored for customers who want immediate landscape impact. In this way we differ from a bedding-plant producer. We sell material of a finished size, budded or blooming as opposed to a bedding-plant operation, which sells

material that will grow into that state of maturity. Because of this we produce only 4-in. pots, 6-in. pots, 1-gal. containers and hanging baskets. Many annuals such as dianthus and vinca that are typically sold as packs we grow in both 4-in. and 1-gal. sizes. This again emphasizes the point that our customers want a finished item and are not willing to wait for a small plant to grow to that level of maturity.

Varietal Selection. Varietal selection is one of the most important considerations in adapting a color program suited to the temperature extremes of the Southwest. In selecting cultivars we look for sales appeal, heat tolerance, uniform growth, and maximum plant size. The plant size should match the size of pot it is sold in. Generally, the crops that perform well for us as a grower are going to perform well for landscape or retail customers.

Heat tolerance is a big factor as there are great variations from cultivar to cultivar. An example of this is pansy selections for fall sales. Pansies are our number one seller in 4-in. size. Many of the older lines such as King Size and Swiss Giants do not perform nearly as well as Majestic Giants or Universals in late summer and early fall heat. We look for cultivars that are going to maintain uniformity and compactness, giving us the longest sales period. For example, petunias are an extremely fast grower that can get quite "leggy" in excessive heat. For this reason we use the Ultra cultivars that provide a uniform growth rate and compactness as opposed to the Cascades, which tend to bolt and "leg out" quite rapidly.

Matching size of pot to plant height is an important consideration in selecting a cultivar. Many geranium cultivars such as 'Red Elite' or the Fischer cultivars, are strictly suited to 4-in. pots. They remain too short to fill out a 6-in. pot so other cultivars, such as 'Sincerity' or 'Yours Truly', which are cutting geraniums, are better suited.

I have discussed mostly herbaceous annuals up to this point. We are also particularly excited about the potential for native color. *Salvia greggii* is an outstanding plant that is adaptable to most areas of the Southwest. It has few insect or disease problems, gets better with each shearing, and blooms profusely from March to October. We are seeing it specified more and more in mass quantities throughout Texas. We believe there will be a definite trend to natives, such as this plant, as water availability becomes a greater concern throughout the Southwest.

Cultural Techniques. What kind of cultural techniques do we use to produce a quality plant adapted for the Southwest? Our climate is one of extremes in south central Texas. High night temperature is one of the biggest problems we deal with during spring and fall. These temperatures cause rampant growth resulting in legginess and often delayed bud formation. On crops that are responsive, we use the growth regulators B-Nine and Cycocel quite

heavily. This helps not only to control growth rate but provides uniformity and compactness. Examples of crops most responsive to B-Nine and Cycocel are petunia, impatiens, vinca, dianthus, and geranium.

I will briefly outline the steps that lead to our finished product. First, we are great believers in plugs as a starting point for our production. They establish in the pot faster, and we have less transplant losses, particularly under extreme heat. They shorten crop timing considerably and offer a big labor-savings advantage. A raw seedling with no self-contained root ball takes a skilled planter to handle. Generally, an unskilled laborer can learn to plant a plug efficiently within hours. This allows us to use less specialized personnel that are available to do a variety of tasks. We presently purchase all our plugs. However, we are considering several seed planters for plug production that are on the market now. Most of our perennial 4-in. production is direct stuck, lantanas, for example. Our 1-gal. material is produced from a transplanted liner, either from a cutting or seedling. Most of our crops are started either under poly or saran and then moved outside or uncovered for finishing. Much of our material is started in small quonset houses under saran. Rather than move plant material out, we remove the saran to another empty quonset and continue planting under it. This is an important factor in providing a product that will withstand the adverse weather patterns of this area. It must be finished and hardened off or it will not have good shelf life or survivability in the landscape. Material finished inside a greenhouse tends to be rather soft and will not have as good a weather tolerance as material finished in an outside growing area.

Crop Timing. One final word on crop timing. Timing is critical to any nursery operation but more so in a color program. Sales windows are extremely short with many annuals and perennials, sometimes as short as one week. Staggered planting programs need to be followed very carefully in order to prevent having too much material available all at once. Our container production is projected by quarters or within three-month periods. Color projections are done by the week. This is a major distinguishing feature between color crops and woody ornamentals. This is the main reason our nursery opted to create an entirely separate department with a different production scheduling program to adapt to the fast cycles of color crops.

GARDEN CHRYSANTHEMUM CULTIVARS FOR SOUTHERN CONTAINER PRODUCTION

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The following cultivars of garden mums are neither totally inclusive nor exclusive. They are those which I have personally seen perform admirably in production in the South.

Characteristics that I look for in selecting cultivars include:

1. Plant habit—is the growth even and pleasing to the eye?
2. Is the plant sturdy?
3. Are the flowers of sufficient numbers and of a form to be pleasing to the consumer?
4. Are the plant and flowers durable?
5. When does it flower?

WHITES

'Minnwhite': Has an excellent mounding habit. This is one of the earliest-flowering cultivars. The plant is very free breaking. The somewhat small flowers are overcome by the profuse budding. 'Minnwhite' can have problems in shipping, and it sometimes breaks open in center of plant.

'White Grandchild': Produces a full plant. The habit is not as mounding as Minnwhite, but the flowers are larger. Blooms about the same time as Minnwhite.

'Penquin': Has a nice compact plant habit but is later than either 'White Grandchild' or 'Minnwhite'.

'Starfire': Well-shaped plant. Somewhat upright, but sturdy. Flowers are larger than 'White Grandchild'. This is a late cultivar, flowering approximately two weeks later than 'White Grandchild'. 'Starfire' would be better for the customer as it would establish before blooming, but he will not buy it green.

'Ballerina': Plant habit much like 'Starfire'. Flower date about the same as 'Starfire'. It looks like a miniature spider.

'White Stardom': A white daisy which has an excellent plant habit. An early flower date.

YELLOWS

'Sunbeam': A beautiful, compact, spreading habit. Small flowers, but very profuse and durable. Is slow to flower, possibly mid-October.

'Goldmine': A strong, compact plant. Flower is an attractive

gold-yellow that keeps well. Flowers in early October or late September. One of the best new cultivars.

'Fortune': Has a strong, compact habit. Flowers are up to 2½ in. across.

'Jackpot': Plant has a stong, cushion habit. Flowers a week later than 'Fortune'. Probably the number one yellow in sales. The last few years it has seemed unusually susceptible to *Fusarium*.

'Yellow Jacket': Has an excellent mounding habit. Very free-breaking and profuse-flowering. Flowers end of September—early October.

'Allure': More attractive daisy form than 'Yellow Jacket.' Flowers 1–2 weeks earlier. Excellent plant habit.

'Minnyellow': Has the same characteristics as 'Minnwhite'.

BRONZE AND REDS

'Grenadine': A color best described as coral bronze that has been very popular. The flowers are from 3 to 4 inches in diameter. The plant has an attractive mounding habit. One of the earlier flowering cultivars in Texas. It is all around excellent, although the color varies with the temperature.

'Ironsides': An orange bronze flower with an even plant habit. A fairly early bloomer but is susceptible to crown buds, which do not develop when exposed to long periods of high temperature.

'Minngopher': Similar to 'Minnwhite' in habit and flower date. One of the best red decoratives.

'Pancho': Has a compact, mounding habit. Same color as 'Ironsides' with some of the same problems. Flowers two to three days later than 'Ironsides'.

'Remarkable': An even plant with a strong red color, which it retains well. Flowers one to two weeks later than 'Minngopher'. An overall excellent plant, and with 'Minngopher', the top red cultivars.

'Ruby Mound': A red that has an excellent mounding habit. Very free branching with a profusion of buds. Color does not hold as well as 'Remarkable'. The cuttings are very sensitive to foliar breakdown in shipping.

'Viking': A full, sturdy plant. Free branching, will have more flowers than 'Ironsides', but flowers one to two weeks later.

PINKS

'Adorn': A true pink daisy, which flowers early. Has a low, spreading plant habit. An overall excellent cultivar.

'Stardom': The number one selling pink for years. Excellent plant habit and early flowering. May "over-petal" and look more like a decorative.

'Stargazer': A sport of 'Stardom' with all attributes of 'Stardom'

and some improvements. Flower is more true daisy and the color is darker. Will flower three to four days later than Stardom.

'Debonair': Possibly the best new cultivar in years. Has even plant growth, free breaking, and sturdy. Most durable flower of all pinks. Flowers early. This should be a must in garden mum programs.

NATIVE ORNAMENTALS FOR THE U.S. SOUTHWEST

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Lone Star Growers, located in San Antonio, Texas, is a wholesale nursery specializing in production of container-grown ornamentals. Besides ornamental shrubs and trees we also grow annual and perennial color crops, tropical foliage, and southwestern natives.

The Native Plant Program developed at Lone Star Growers is based on company philosophy that we owe something to the community in which we make our living. We are introducing to the trade plants that are well adapted to their environment. Texas is facing a growing water crisis, and plants must be drought tolerant as well as hardy to survive. Although the skepticism was great at the time that the program would not be economically feasible, Lone Star believed then, as it does now, that native plants are the way of the future.

The program itself started as an introduction department where species could be evaluated in several areas: their ornamental value, hardiness, and regional adaptability; and also where their propagation techniques and cultural needs could be determined.

Over 800 species from Texas and surrounding areas have been collected and are currently being evaluated. In the past three years we have brought over 200 into commercial production.

Over the last two years we have seen an explosion in the interest and demand for natives in the industry. The promotion of natives through Xeriscape, the Texas Department of Agriculture and county extension agencies have gone a long way in creating an acceptance of native plants as useful ornamentals.

In response, this past spring has brought the development of a new department solely devoted to the production of natives from propagation to large container specimens. This department will be able to offer a wide range of natives to the consumer, rather than

and some improvements. Flower is more true daisy and the color is darker. Will flower three to four days later than Stardom.

'Debonair': Possibly the best new cultivar in years. Has even plant growth, free breaking, and sturdy. Most durable flower of all pinks. Flowers early. This should be a must in garden mum programs.

NATIVE ORNAMENTALS FOR THE U.S. SOUTHWEST

AGNES C. HUBBARD

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Lone Star Growers, located in San Antonio, Texas, is a wholesale nursery specializing in production of container-grown ornamentals. Besides ornamental shrubs and trees we also grow annual and perennial color crops, tropical foliage, and southwestern natives.

The Native Plant Program developed at Lone Star Growers is based on company philosophy that we owe something to the community in which we make our living. We are introducing to the trade plants that are well adapted to their environment. Texas is facing a growing water crisis, and plants must be drought tolerant as well as hardy to survive. Although the skepticism was great at the time that the program would not be economically feasible, Lone Star believed then, as it does now, that native plants are the way of the future.

The program itself started as an introduction department where species could be evaluated in several areas: their ornamental value, hardiness, and regional adaptability; and also where their propagation techniques and cultural needs could be determined.

Over 800 species from Texas and surrounding areas have been collected and are currently being evaluated. In the past three years we have brought over 200 into commercial production.

Over the last two years we have seen an explosion in the interest and demand for natives in the industry. The promotion of natives through Xeriscape, the Texas Department of Agriculture and county extension agencies have gone a long way in creating an acceptance of native plants as useful ornamentals.

In response, this past spring has brought the development of a new department solely devoted to the production of natives from propagation to large container specimens. This department will be able to offer a wide range of natives to the consumer, rather than

growing the faster and easier to grow to the exclusion of the others. The Research and Development department will continue to evaluate new natives and make selections of superior cultivars. We are donating plants to other area nurseries for evaluating hardiness.

For many years the word "native" was considered synonymous with "weed" by a large number of people. This idea is an obstacle we still face despite growing popularity of the natives. There are other misconceptions that will cause problems in the long term.

Most of the misconceptions stem from lack of knowledge of the plant material. One of the most serious mistakes made is interpreting *low* maintenance as *no* maintenance. Native plants are just as varied in characteristics as other plants. The oversimplification of their care can only lead to disappointment.

The use of natives in landscapes is growing but still seems to be limited too many times to the "wild" or naturalistic landscape. In order to establish a solid market, natives will have to be mainstreamed in both formal and informal landscape designs along with accepted ornamentals.

Some of the most popular natives are already close to losing their native identity but many of the 200 plants that Lone Star is growing are still very new to the trade. Outlined here are some that promise to be real winners in the near future.

TREES

Chilopsis linearis 'Burgundy Lace' (TM), desert willow, is a small deciduous tree which has been in cultivation for many years but has not been widely used. The tubular flowers are about 2 in. long and are produced throughout the summer. 'Burgundy Lace' (TM) was selected for its solid burgundy flowers. With its attractive blooms and adaptability to many soils and cultural conditions, this tree should be planted more. It is propagated by semihard or hardwood cutting.

Ungnadia speciosa, Mexican buckeye, is native throughout central Texas and northern Mexico and is one of the outstanding natives. It grows as a tree or a large multistemmed shrub and can reach 30 feet high. The deciduous foliage is similar to a pecan; the rose-colored flowers, which appear before the leaves, makes this tree from a distance resemble a redbud. Mexican buckeye will bloom at an early age, sometimes when only one year old. This gives Mexican buckeye a distinct advantage over many flowering trees that may take years to bloom. It is easy to grow and is adapted over most of Texas and Louisiana. Propagation is by seed collected in late summer. Seeds need no pregermination treatment.

Diospyros texana, Texas persimmon, is a small multitrunked

tree reaching 30 feet but is usually only 10 to 15 feet. Its most outstanding features are the intricate branching and smooth gray bark. The leaves are persistent to deciduous depending on the severity of the winter. The females bear black edible fruit approximately 1-in. in diameter. Propagation is by seeds, which need no pregermination treatment.

Myrospermum sousanum, arroyo sweetwood, is a newly discovered species. It was found in April, 1982, by a party lead by our native plant expert, Mr. Lynn Lowrey, in the state of Nuevo León, Mexico. This is a beautiful flowering tree with light green deciduous foliage. It may reach up to 40 feet. Arroyo sweetwood is a profuse bloomer, producing white legume flowers in terminal spikes through April. The tree has proven to be adapted to south and central Texas. Seed matures in late summer and need no pregermination treatment.

Quercus polymorpha, 'Monterrey oak', is a large evergreen spreading oak, similar in shape and size to *Quercus virginiana,* southern live oak. Monterrey oak has large leathery leaves up to 7 in. long and the new growth has an attractive reddish cast. This tree will provide an attractive alternative to the southern live oak in Texas.

SHRUBS

Rhus virens, evergreen sumac, is one of the best evergreen shrubs for hot, well-drained locations where many exotics will not survive. It is a rounded shrub, which can reach 10 feet but can be sheared for hedge plantings. It is adapted over most of Texas. Propagation is easiest by seed, but it can also be propagated by cuttings. Seeds need scarification.

Berberis trifololata (Mahonia trifoliolata), agarita, has evergreen, holly-like leaves. It forms a dense, rounded shrub usually to 6 feet. Agarita is one of the earliest spring bloomers in Texas, with yellow fragrant flowers in March. The flowers are followed by edible red berries. Agarita is very drought resistant and adapted throughout Texas as long as it is given good drainage. It grows best in full sun. Seeds require cold stratification.

Bauhinia congesta, Anacacho orchid tree, is more often seen as a large multistemmed shrub up to 20 feet tall. This deciduous shrub is only found in one place in Texas, the Anacacho Mountains in southwest Texas. But, it is also native throughout northern Mexico. This bauhinia has small emerald leaves, which are cleft to the petiole. It produces an abundance of white flowers in March and April, continuing on and off throughout the summer. This bauhinia is adapted throughout the central and southern portions of Texas. Seeds germinate easily with no pregermination treatment.

Bouvardia ternifolia, scarlet bouvardia, is an outstanding perennial. The scarlet tubular flowers are 1 to 1½ in. long and are borne in terminal cymes. It blooms from midsummer to frost and is adapted throughout central, west and south Texas, up into New Mexico. Bouvardia does best in well-drained soils and in full sun. Propagate by semihardwood cuttings throughout the growing season.

Chrysactinia mexicana, damianita, is a mounding evergreen perennial reaching 12 to 15 inches. The dark green foliage is very aromatic. Golden yellow blooms are produced all summer. This little evergreen shrub can be used in rock gardens, borders, and edging. It does best in full sun and in well-drained soils. Damianita is adapted through central and west Texas.

Salvia greggii, autumn sage, comes in a variety of color selections including red, coral, white, pink, and burgundy. This has been one of our most popular newcomers. As well as blooming profusely all summer, this woody perennial is also evergreen in central Texas. It is widely adapted throughout the state, very drought resistant and a versatile native. Propagate by seed or semihardwood cuttings.

Pavonia lasiopetala, rock rose, is a very showy drought resistant native with pink hibiscus-like flowers. It will grow in full sun or light shade. When mature it is 4 feet by 4 feet. Deciduous.

Poliomintha longiflora, Mexican oregano, is used as an herb in the markets of Mexico. The small evergreen leaves smell very much like the commonly-used spice oregano. In addition to this it produces light lavender flowers throughout the summer. The combination is a striking landscape plant. Full sun and well-drained soils are preferred. Propagation is easy by semihardwood cuttings.

Unfortunately, space is limited, and I am only able to describe a few of the many beautiful natives available in the trade today.

I would like to end with something Mr. Lynn Lowery once wrote: "If we judge the natives' quality and usefulness by how similar they are to common plant material, their main value will have been discarded. We have the opportunity of greatly enlarging the possibilities in plant use if an open mind prevails."

NEW PLANT INTRODUCTIONS WITH STRESS TOLERANCE TO CONDITIONS IN THE SOUTHERN GREAT PLAINS[1]

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Abstract. Plants of the Great Plains are exposed to a wide variety of environmental stresses. The most demanding of these stresses is the often harsh and variable continental climate. A number of plants that are tolerant of these stresses and are of ornamental value have been recently introduced in the trade. Some of these plants are improved native plant selections; others are the products of years of breeding programs or from plant exploration trips to regions of the world with similar soil and climatic conditions. This paper emphasizes plants that can be propagated commercially.

INTRODUCTION

Plant hardiness zone maps indicate only minimum winter temperatures, whereas plants must endure many other stresses of the climate in the often-arid Great Plains region, including summer heat, drought, and wind, plus desiccation of cold and dry winters. Ornamental and windbreak species have been evaluated extensively for this region at the southern Great Plains Field Station since its establishment in 1914 at Woodward, Oklahoma. Although ornamental research has been discontinued at the site, this station was instrumental in introducing a host of hardy, drought-tolerant species still in prominent use today. Included in the early plantings were numerous species of *Celtis, Cercis, Juniperus, Pinus, Pistacia, Prunus, Quercus, Ulmus,* and many others (4). Examples of plants still in prominent use today as a result of early testing are the Chinese pistache, *Pistacia chinensis,* goldenraintree, *Koelreuteria paniculata,* and lacebark elm, *Ulmus parvifolia.*

In recent years many plants that will tolerate the extremes in environmental stress associated with the Great Plains have become available to the nursery industry. The following list is not all-inclusive but enumerates many selections that have performed well at the KSU Horticulture Research Center at Wichita, Kansas. Temperature extremes range from −15°F (−26°C) to 110°F (43°C) with annual rainfall of 28 to 30 inches per year. Irrigation is supplied for establishment and, in many cases, continually for the best performance of some of these ornamentals, but all the species have tolerated severe extremes in climate. Where feasible, the methods of propagation are indicated.

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Acer ginnala 'Compactum', compact amur maple: A very dense and compact form with consistent wine-red fall color that is propagated from softwood cuttings in June using 1,000 ppm IBA (1). A recent cultivar introduced by SCS is 'Flame', which has brilliant fall color and is propagated by stratified seed. The color varies with seedlings.

Acer saccharum, sugar maple: Although leaf scorch affects many cultivars, greater tolerance has been observed on Caddo maples (from Caddo County) and the Wichita mountain maples in Oklahoma. Promising new selections of hard maple include *A. s.* 'Legacy', 'Commemoration' and *A. nigrum* 'Green Column'. Propagation is by seed or budding on seedling understock.

Acer truncatum, shantung or purpleblow maple: An Asiatic species reaching 30 ft. that performs well under heat and drought stress; resistant to leaf scorch, insects, and disease. Propagation is by seed or softwood cuttings (9).

Celtis sinensis, Chinese hackberry: One of three attractive, smooth-barked species with orange fruit. It is of borderline hardiness north of zone 7. Plants grown from seed collected on the University of California campus, Davis, California, have been surprisingly hardy at Wichita, Kansas, and have shown no gall or witches-broom. Another smooth-barked species, sugar hackberry, *C. laevigata,* also appears to be resistant to witches-broom. The cultivar 'All Seasons' is an improved selection from Illinois with a dense crown and small leaves having greater luster. Propagation is difficult but possible by both budding and softwood cuttings.

Crataegus phaenopyrum, the Washington hawthorn: Ornamental features include reddish-orange fall color, persistent orange-red fruit, and moderate resistance to rusts. Often grown in natural, clump form, it can be easily trained to a single trunk. Improved tree-form selections, grafted on seedling understocks, are 'Manbeck' and 'Vaughn', a reported hybrid with *C. crus-galli* having larger fruit. Two excellent thornless species are cockspur hawthorn, *C. crus-galli* var. *inermis* with crisp, glossy foliage and oakleaf hawthorn, *C. pinnatifida,* although the latter has been obscure in the trade. Summer and winter seed stratification have been more successful for breaking seed dormancy than acid scarification in our trials.

Maclura pomifera, Osage-orange, also called bois d'arc: This tree has proven to be a good plant for the Great Plains due to its extensive use as a windbreak species. Recent interest in the species as an urban tree for difficult sites has produced numerous male and usually thornless cultivars, such as 'Altamont', 'Fan D'Arc', 'Park' and 'Wichita'. Propagation is by budding, softwood or hardwood cuttings (8).

Malus species and cultivars, flowering crabapple: Numerous

recent introductions offer exciting new forms and flower colors with resistance to scab and other diseases plus good winter fruit retention (3). Species and cultivars performing well in our trials are 'Adams', *M. baccata* 'Jackii', 'Donald Wyman', *M. sargentii, M. sieboldii,* var. *zumi* 'Colocarpa' and 'Snowdrift'. Promising new cultivars include 'Brandywine', 'Christmas Holly', 'Molten Lava' and 'Sugartyme'. Propagation was formerly by budding or whip-and-tongue grafting on seedling or clonal understock. It is now achieved by rooting hardwood and softwood cuttings (1, 11).

Pistacia chinensis, Chinese pistache: Although grown at Woodward, Oklahoma since 1933 and proven hardy in Wichita, Kansas for 30 years, this tree is still under-utilized. Its extreme drought tolerance, pest resistance, and dependable fall color make this dioecious species a welcome addition to contemporary landscapes. Propagation has been primarily from stratified seed, although spring sowing requires less chilling (5). Germination is erratic. Opportunities exist for improved cultivars, both male and female, but limited success has been reported by both budding and softwood cuttings (7).

Quercus acutissima, sawtooth oak: A native of China, Korea, and Japan, this fast growing, drought-tolerant oak has shown considerable promise even in western Kansas in recent tests. Its tolerance to heavy, clay soils has also been extremely good. Shingle oak, *Q. imbricaria,* also shows promise throughout Kansas but is scarcely available in the trade. Acorns of both species should be sown as soon as ripe or stratified 60 to 90 days.

Ulmus parvifolia, lacebark elm: This tree is a more desirable elm than the name implies. As a true Chinese elm it is often confused with the Siberian elm, *U. pumila.* Although introduced to the Plains states in 1928, the lacebark elm with attractive mottled, orange and gray bark, has not been widely used. It is resistant to Dutch elm disease and moderately resistant to elm leaf beetle and hardy to zone 5. Much seedling variation occurs but there have been few improved selections made. *U. parvifolia* var. *koreana* has smaller leaves than the species. A recent Oklahoma introduction, 'Prairie Shade', is propagated by softwood cuttings in June (12). Seed viability is usually poor; seeds should be collected in late October and sown soon after harvest. The low germination percentage prevents this elm from being a "weed tree".

SHRUBS

Aronia melanocarpa, black chokeberry: Similar to *A. arbutifolia* but with less leaf scorch. Primarily a wildlife species, it doubles as a large shrub or hedge plant 6 to 7 feet tall with glossy green foliage, which turns a rich burgundy fall color. This aronia has purplish to black, grape-size fruit. It tolerates a wide variety of

soils from sandy and dry to wet, clay sites. Cuttings taken in early summer root readily without hormones, or it can be propagated from seed stratified for 90 days at 40°F (1).

Ilex × *meserveae (I. aquifolium* × *I. rugosa),* blue hollies: Probably the most exciting, hardy, holly hybrid introduced in recent years. This group is not as heat-tolerant as most Asiatic holly. Very hardy and most fruitful is 'Blue Princess'. The male, 'Blue Prince' is a hardy and attractive pollen parent. Somewhat more tender is the female cultivar 'Blue Angel' with dark purplish winter foliage.

Ilex decidua, deciduous holly or possumhaw: This large shrub or small tree is a native of southeast Kansas and Oklahoma. It has very persistent winter fruits and is adaptable for naturalizing. Improved cultivars include a vigorous upright Oklahoma selection, 'Warren's Red', and numerous introductions from Illinois with superior fruiting such as 'Council Fire', 'Pocahontas' and 'Sundance'. The species has shown better growth and less leaf scorch than *I. verticillata,* which is more popular in the northeast; however, *I. verticillata* cultivars 'Afterglow', 'Cacapon', and 'Winter Red' exhibit very attractive winter fruit. Deciduous hollies have a deep seed dormancy and are also difficult to propagate from cuttings. They seem to root best when taken after frost or by mid-October and treated with Hormodin 3 (2, 10).

Ilex cornuta × *I. ciliospinosa:* Hybrids with somewhat greater hardiness than 'Burford' holly. The two best cultivars at Wichita have been 'William Cowgill' (female) and 'Harry Gunning' (male). *I.* 'China Girl' [*I. cornuta* × *I. rugosa*] combines the heat tolerance of Chinese holly with the hardiness of a hardy Japanese species. It has performed very well in recent years under a variety of conditions (6).

Lagerstroemia indica, crapemyrtle: Normally a southern plant, the species performs as an herbaceous perennial in zone 6, usually killing to the ground but blooming on new growth from July to frost. Of dwarf cultivars evaluated, hardiest have been 'Centennial', 'Dwarf Blue', 'Hardy Lavender', 'Royalty', and 'Victor'. Softwood cuttings root in three weeks under mist without the aid of hormone. Two promising new Oklahoma introductions are 'Prairie Lace' and 'Centennial Spirit'.

Rhododendron species, evergreen azaleas: Although requiring special soil amendments such as sulfur and sphagnum peat moss to acidify planting beds, several selections with more cold hardy flower buds that bloom consistently at Wichita include 'Hino-crimson' and Gable hybrids such as 'Fuchsia', 'Herbert', and 'Purple Splendor'. Softwood cuttings placed under mist in June treated with 1,000 ppm IBA root quite successfully. Evergreen rhododendrons and hybrids such as *R. cardinianum* × *clauricum* 'PJM' and 'Olga' have very hardy flower buds. Buds may blast in August if not protected from intense heat.

Viburnum species and hybrids: New U.S. National Arboretum introductions of semi-evergreen selections such as 'Chesapeake' and 'Eskimo' have performed quite well. They have sturdy white inflorescences and attractive foliage. *V.* × *rhytidophylloides* 'Allegheny' has shown superior heat tolerance and excellent foliage characteristics in full sun. Propagation is easily accomplished by softwood cuttings using a 5,000 ppm IBA dip. Allow cuttings to break dormancy the following year before lifting from outdoor beds.

In warmer regions this list could be expanded to include more tender species and cultivars. The diversity of plant materials has greatly increased available species for use in the southern Great Plains. Even greater success can be achieved by proper site selection and improvement of the planting environment. Some otherwise borderline selections will then perform satisfactorily.

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EFFICIENCY TECHNIQUES IN PROPAGATION: FOG SYSTEMS

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The system we have at Cypress Creek Nursery is the MEE II fog system. Mee Industries is based in San Gabriel, California; their system is used nationwide for cooling, propagation, and freeze protection. We use the system for propagation and have for a year and a half.

The system is designed to fog 11 double-poly, gutter-connected houses each 108×21 ft. The total area is approximately 25,000 ft.^{2} There are two fog lines in each house suspended 6 feet from the ground. Copper tubing is used in order to withstand the pressure. The 5 H.P. motor pumps water into the system at the rate of 7.3 gal./min. at a pressure of 900–1000 psi. Maximum pressure is 1000 psi.

There are 20 nozzles in each house, 10 nozzles per line spaced 10 feet apart. There are 2 types of filters built into the system. A bullet filter is placed in the back of each nozzle, and 4 cylinder filters fit into the holding tank. Bromide sticks are used in the holding tank to prevent fungus growth in the fog lines.

The system can be run by a timer, humidistat, or manually. We choose to run our system by humidistat suspended in the propagation house. A light bulb attached to the humidistat helps to evaporate the moisture as it is pulled through the humidistat by a small fan. The light bulb in effect keeps the humidistat probe dry, causing the system to stay on longer to keep humidity high. We feel it is important to keep the humidity as close to 98% as possible; this makes it ideal for growing conditions in these houses.

There are some advantages and disadvantages with the system. The main problems we have experienced are:

1. Breaks in the lines. This problem has been virtually eliminated by replacing original fittings with high-pressure fittings.
2. Nozzles stopping up. We've tried soaking them in muratic acid, lasering the orifice, and blowing them out the opposite direction. No solution has been found yet, but lasering does seem to work the best.
3. Heat buildup in the house. We've worked with Mee Industries on this, and we have found that painting the tops of the houses with whitewash paint has lowered the

[1] Propagation Manager

temperature 10 to 15°F.

4. Dry areas. Supplementary water is still used when needed. The main areas where we have problems are around the doors.

Advantages in the system are:

1. Increased production and efficiency. The system has cut the rooting times down of certain plants, some as much as half the usual length of time. Plants are never under stress.
2. Moisture. Does not get too wet even with high humidity in Florida.
3. Service. Mee Industries has become much better than in the beginning when the system was first installed.
4. No problem with working conditions. The employees don't seem to mind the fog; the only problem is that it is hard to find them.

If I were installing another Mee system, I feel that it would be beneficial to install a better and more efficient water filtering system for purifying the water before it gets into the system. This would decrease the amount of problems within the lines and nozzles themselves.

All in all, the system has worked well for us. There are still problems to be worked out, but we have found it to be very effective. The fog system has increased our production and improved our efficiency in propagation.

EFFICIENCY TECHNIQUES IN PROPAGATION: BOTTOM HEAT

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We are always looking for the best system for root growth on our cuttings and a better and more efficient way of heating our propagation area. After looking at many different methods used throughout the indoor foliage industry in our area, we installed a hot water, bottom heating system. We decided to use a boiler we already had on the nursery. The only problem we had was that our boiler was being used for steam. Once we had the boiler changed over to heat water, rather than produce steam, we were ready to begin construction.

In the summer of 1984, we hired an engineering firm to design the system and assist us with the installation. The total area we were going to heat was 25,000 ft.^{2}. Our boiler was a Kewanne, 1,800,000 B.T.U. heating capacity.

The system consists of 3-in. main lines running from boiler on the discharge side to the middle of the greenhouse. From there it branches both ways down the middle of the greenhouse with 2½-in., 2-in., 1½-in., and 1-in. pipe. These main lines are then connected to header pipes that are 9½ ft. long. On the header pipes are 19 half inch thinwall PVC pipe that run the length of the beds to another header pipe. These beds are 50 ft. long and the PVC pipes are spaced every six in. There are four beds per house, and each house is 108 × 21 ft. We have a 2-ft. walk down the middle of each house.

The header pipes at the end of each bed are connected to the return lines that take the water back to the boiler to be reheated. On these headers we have a valve to bleed the air out of each bed.

All the header pipes are connected to both the main line and return lines with rubber PVC pipe. The glue was a special grey PVC glue used for heating systems. All the pipe for the heating system was installed in the ground.

The water from the boiler is pumped out at 115°F and returns to the boiler at 95°F. The water is pumped through the system by a five H.P. centrifugal pump mounted on the return side of the boiler. The boiler is equipped with many safety devices to prevent water from getting too hot or too cold or building up too much pressure or from having a burner misfire, just to mention a few.

The whole heating system is controlled by a soil thermostat located in a pot filled with soil in the middle of the greenhouses. Our

[1] Production Manager

system is set to maintain 70°F soil temperature during the months that we heat. With soil temperature at 70°F the average air temperature is 60°F.

The advantages are constant 70°F soil temperature; more even distribution of heat; quicker rooting times, which yield faster turnover of crops; and cost efficiency. The disadvantages are trapped air in lines that stops water flow, the main problem, and ruptured lines due to the thinness of the pipe wall and the fact that people step on the lines.

The boiler heats 25,000 ft.^{2} of growing area at a cost of 29¢ per ft^2. From the first of November, 1985 to the end of February, 1986, we used 7500 gal. of diesel fuel at an average cost of 97¢ per gal. Using half 2¼-in. pots and half 3½-in. pots, the 25,000 ft.^{2} of growing area will hold approximately 500,000 units at one time. During that four month heating period, we will turn two crops or 1,000,000 units. This gives us a cost of .00725¢ per pot for heating.

It has been our observation that during the winter months, the harder to root plants such as *Raphiolepis, Juniperus* spp., and *Ilex* spp., root in four to five weeks and are ready to move out in six to eight weeks for planting. The easier to root material rooted and was ready to move out for planting in two to three weeks.

We at Cypress Creek Nursery have been very pleased with the hot water unit for heating. The faster production of the liners has been, by far, the most cost effective change. The unit once installed and running properly has proved to be far better than we had anticipated.

EFFICIENCY TECHNIQUES IN PROPAGATION: METHODS AND PROCEDURES

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Efficiency is a measure of production compared to cost of time, money, and energy input. How often have you said to yourself or told others that you could have done more except you ran out of time or money or energy? We do not have unlimited resources so our task is to maximize productivity within our resource means.

EFFICIENCIES IN PERSONNEL AND LABOR

Consider how many decisions are required to make a propagation department run smoothly and effectively. Decisions are made by people that are armed with facts, figures, experience, and sometimes instinct. Labor expenditures represent the best area to capitalize on efficiencies. As much as any other part of a nursery, the propagation department should be staffed with good decision makers.

Management: Management should provide leadership, set goals, and provide resources. Production targets are set prior to the propagation season, but they are reviewed constantly. Production targets are determined by input from sales data and sales staff's opinions and produce merchandise for which there is a market. A well thought-out production plan can move your nursery towards prosperity, providing you with generous supplies of salable plants. Depending on the type of nursery one has, the production plan you conceive today will correlate directly with your success 12 months, 24 months, or 36 months from now.

A good manager will provide adequate amounts of supplies, observations, ideas, facilities, equipment, and personnel for his propagation department. Managers should understand the overall picture and grasp situations as they are and are likely to be. Experience is irreplaceable and becomes more valuable each year. A good manager rewards achievement and shares prosperity. He has compassion but not to a fault.

Supervision: An efficient supervisor is honest, communicative, personable, predictable, concerned, intelligent, motivated, resourceful, and dedicated. Deficiencies in these characteristics distract from his or her ability to work with management and labor. Initially supervisors are problem solvers and they grow into problem preventers. Supervisors have primary responsibilities to management. However, they are also responsible for labor's morale and fair treatment.

Foremen: Foremen should be honest, communicative, enthusiastic, concerned, motivatable, or motivated, resourceful, and dedicated. She or he is likely to be concerned about efficiencies of day-to-day operations. Foremen oversee activities of five to 10 people.

Labor: An ideal laborer is dependable, pleasant, free of persistent personal problems, resourceful, honest, motivatable and perfectly adapted to piecework. Management does not suffer from excessive loan requests, sour attitudes, absenteeism, deception, and low productivity with this type of employee. An efficient laborer makes piecework consistently and, in fact, cannot maintain his standard of living on the guaranteed wage. This type of employee responds to non-piecework jobs with speed and enthusiasm, in haste to return to a piecework job. Good laborers such as mechanics, truck drivers, and watermen who do not get the opportunity of piecework must be paid enough to retain their services.

Small nursery owners may find themselves playing management roles or labor roles, whichever is the case. Time, money, and energy expenditures versus production must be carefully evaluated under these circumstances. Efficient utilization of labor represents fertile ground for increasing profit.

EFFICIENCIES OF FACILITIES

Efficiency, propagation techniques, and procedures cannot be discussed without reference to physical facilities operated. There are three cornerstones that will allow a nursery to survive and progress; people, plants, and facilities. One cannot hope to be efficient with an inefficient greenhouse, rooting areas, or growing beds.

Propagation facilities need to be economical to build and maintain. The cost of construction will vary, mostly due to climatic conditions encountered in summer and especially in winter. Along the Gulf Coast a gutter-connected greenhouse designed to root azaleas, hollies, and other broad-leaved ornamentals can be built for $1.30/ft.^{2}. A greenhouse normally is unnecessary to the production of photinia, juniper, and Chinese-holly liners. In this case a full-sun mist area, properly shaped and prepared, is the economical facility to build. Mist areas under saran shade houses along the Gulf Coast are adequate to root many euonymus and azaleas.

Cutting sheds, greenhouses, mist areas, and storage buildings should be designed to make work easier, rather than more difficult. One should plan adequately to match equipment utilized and facility design. Permanence is a key consideration in the construction of propagation facilities.

EFFICIENCIES IN EQUIPMENT

How does one decide on the equipment necessary to use in a propagation department? Sometimes the question is clear. "Yes, this piece of equipment is necessary because: 1) It will lower my production cost; 2) It will increase my production; 3) It saves time; 4) It will reduce the energy required to get the job done; 5) I cannot get the job done without it."

Areas where equipment can be used are soil preparation, seed cleaning, flat filling, soil testing, business managing, trimming, communicating, material handling, transporting, heating, cooling, pest control, shipping, and others.

There is no question certain pieces of equipment are absolutely necessary. Telephones are critical to communication with customers, friends, and suppliers. A small grower who is responsible for most phases of his production should consider a portable telephone combination with the ever-dreaded recorder. Larger companies, such as Flowerwood, rely on FM radio systems to maintain communication lines. If a machine pays for itself, you need it.

Large computers for large nurseries are essential for accounts receivables, payroll, invoicing, shipping, sales, inventory, bookkeeping, and production planning. Electric golf carts are reasonably priced and useful to move around in propagation areas. Gasoline or electric clippers are fast and easily used to trim large groups of liners. One can afford to spend $2200 to purchase an Orion 940 selective ion analyzer with NO_3 electrode and a Beckmann solubridge to perform leach tests for nitrate, salts and pH if it pays off in improved production.

EFFICIENCIES IN CHEMICALS

Significant advances have been made in the use of chemicals in nursery production. As a result good nurseries have become very plentiful. Growers used to battle leafspots, root rots, blights, and other plagues with little more than their possessed art of growing plants. Modern chemistry now provides effective fungicides such as Subdue, Aliette, triforine, and Benlate to do battle on these fungus pests. Modern chemistry has made possible the use of Ronstar, OH-II, Rout, Surflan, and other herbicides to help solve the weed problem. Modern chemistry annually provides better and safer insecticides.

Science has allowed nurserymen to win the war of resistance in fighting spider mites and will provide answers to the troublesome western thrips currently posing a new problem to nurserymen in the South. Nurserymen need to be attuned to new weapons, each year discontinuing ineffective, outdated chemicals and incorporating new and better pesticides.

Another important scientific advance for horticulture is the

improved formulation of fertilizers. Container growers do not think in terms of tons per acre. They measure pounds per yard, grams per container, and parts per million when they fertilize. When thinking of nursery fertilizers, many have determined that good fertilizer does not cost; it pays! Therefore, nurserymen are willing to purchase premixes, slow-release and liquid N-P-K fertilizers that are expensive per ton but very cost-effective and dependable. Modern nurserymen are meticulous in their fertilizer application.

Rooting compounds are also great chemical tools available to nurserymen. IBA, NAA, their mixture, and now another group of their phenol derivatives have transformed propagation procedures in many nurseries. The use of these chemicals is very rewarding, and one should make advances and changes yearly as he experiments and learns.

EFFICIENCY IN PIECEWORK

Our challenge of high production and quality control can largely be accomplished with the piecework system. This system stimulates production and rewards accomplishment.

To establish a piecework system three criteria should be established:

1. Procedures—Step 1, step 2, step 3, and on to completion
2. Specification—Quality control
3. Expectation—Number per hour

Without piecework or accountability a laborer will give 50 percent performance. Just accountability will give you 75 percent. Rewarding production gives you 100 percent effort. An employer can set a cost rate that is acceptable and fair to the employee and himself.

Examples of piecework rates:

Job description	Cost per unit
Throwing dry fertilizer on beds	$0.002/linear ft.
Putting new 2¼-in. liner pots into trays	0.095/tray of 64
Putting soil into trayed liner pots w/shovel	0.086/tray
Moving liner trays from houses to areas	0.12/tray
Dividing and replanting lirope	0.02 each
Trimming liners with electric clippers	0.02/tray
Boxing liners	3.50/1000
Cutting, stripping, & sticking *I. crenata* hollies	0.0076 each
Cutting, stripping, dipping & sticking *I. cornuta* hollies	0.0097 each
Cutting, stripping, dipping, scaring, and sticking camellias	0.0115 each

To establish a piecework rate, you can use your best employee's

performance and determine the value of that performance to you. Or you can perform the job yourself for a certain time, count your performance, determine the fair and expected performance rate and establish a cost.

EFFICIENCY SPECIFICS

Flowerwood Nursery propagates 75% of liners produced by cuttings. The remainder are produced by seed and division. Propagation by cuttings, if possible, is the most reliable method. However, at times we do not have the knowledge and ability to use cuttings. Therefore, we rely on other methods such as seed germination.

Seed germination of *Chionathus virginicus* is a 2-year process. Fringe tree seed are generally scarce also. In an attempt to propagate it asexually, we were successful in rooting only 2 percent of the cuttings made. The liners that were produced were grown on and the cuttings made from that group rooted with 80% efficiency. Propagation efficiency is a goal to obtain, and things may happen slowly at first. But efficiency is obtainable with patience. We are looking for more and more success with each generation of asexually-propagated fringe trees.

EFFICIENCY OF TISSUE CULTURE

Micropropagation of tissue-cultured plants has brought the development of several laboratories with heavy investments whose purpose is to compete with conventional methods of propagation. Just how these businesses are to fit in with conventional nursery business or how well they can complement or compete has not yet been determined.

The laboratories require heavy capitalization. Sanitary, controlled conditions and expensive equipment are necessary. Hundreds of thousands of cultures, which can involve several million plants, can be propagated in only a few hundred square feet. The facilities are still heavily labor-dependent. This is an area of inefficiency. To date not many woody ornamentals are tissue cultured but successful examples are: raphiolepises, nandinas, and rhododendrons. Most labs have relied more on soft herbaceous species because they are easy and quick to produce. Ferns, daylilies, orchids, and assorted foliage items are easily propagated by tissue culture; consequently, everyone is doing them.

There is a future in micropropagation in the ornamental line of plants. Production of desirable genotypes that are disease-free and in high demand, will allow successful labs to fill voids and be very compatible with the nursery business as we know it today. Tissue culture labs should be conscious of the law of supply and demand and not overproduce. *Nandina domestica* 'Harbour Dwarf' has been

oversupplied by numerous tissue culture laboratories. The result is lower, less profitable prices at all levels of production.

We all have opportunities to increase efficiency. If you are operating exactly the same as you did 12 months ago, you are failing and your competition is gaining. Be flexible, progressive and open-minded to progress. Avoid following nursery tradition because of tradition. Set a tradition of change, progressiveness, and leadership; the result will be an increase in production, efficiency, and growth.

EFFICIENCY TECHNIQUES IN BALL & BURLAP PRODUCTION

DENNIS V. McCLOSKEY
Windmill Nurseries, Inc.
Route 4, Box 180
Franklinton, Louisiana 70438

Growing plant material in the ground has been around from before the time of Christ, but even with this vast span of time only the last 25 years have given us any real technical advances.

The shovel has given ground to the hydraulic spade. The hand-tied ball has been replaced in part by the wire basket. The in-row tractor has totally replaced the mule and Georgia stock. The forklift and pallet are quickly replacing the strong back and weak mind. Irrigation and anti-desiccants are extending the harvesting time. Various containers and concepts are helping overcome the shelflife problem of unplanted ball and burlap (B&B) material, and advances in the use of herbicides have all but eliminated the eyehoe.

But given these few changes in contrast to the many technical advances that have taken place in the last 2,000 years, in-ground growing of plant material, with its antiquated methods, still remains the very best way to grow and transplant many kinds of plants and trees.

At Windmill Nurseries, Inc. about 50 percent of our gross sales comes from the production of B&B material and I would like to give you details of several practices that we utilize in increasing our efficiency.

Hydraulic spades used on track-mounted skid loaders are by far the most efficient application for Windmill. We process the ball directly onto the haul-out wagon, thus eliminating the haul-out process. This requires additional wagons, but they soon pay for themselves.

The use of a ball ring keeps the ball in the upright position

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The use of a ball ring keeps the ball in the upright position

during processing, thus eliminating a few extra hands. These rings are constructed from ½-in. galvanized pipe at a minimum cost.

A five-man crew per machine can harvest one semi-load of 24-in. balls per eight-hour day consistently, which is approximately 150 units, or 80 units of 32-in. balls, or 40 units of 40-in. balls. These balls are what we call "truck ready"; that is, palletized, trunks wrapped, and tops tied. The loading crew can go directly from the digging wagon on to the truck for shipping without any further processing. The floor of our haul-out or processing wagons has pallets, eliminating the need to muscle these large balls around and onto pallets.

Forklifts and pallets during the loading process have virtually taken the work out of handling and loading B&B stock. I do not think that we could hire the people any more who would muscle these plants from the ground onto the semi-trailer trucks as we did in the past. This is not to consider the injuries and strain and insurance risk that today's nurserymen must endure.

We construct our own pallets, which are 5-ft. wide by 4-ft. deep, with a solid top, made with treated pine lumber. The box is tapered as we have found we can distribute the weight along the sides by making the bottom narrow. This helps reduce the tremendous weight on the bottom. The cost is about $22.00. I can assure you that we have tried all other alternatives in constructing these pallets.

We use burlap rather than treewrap. It is cheaper and provides a better cushion.

The use of tree booms that fit over the fork of our lift trucks has tremendously increased our efficiency in handling 32-in. and 40-in. balls. It takes about two hours for three men to load a semi with 32-in. or 40-in. balls using the tree boom, and there's not a bit of heavy lifting in the process. We construct these booms in our shop out of mostly scrap materials for less than $150.00 each.

Our use of narrow-row tractors with limb guards has given us the ability to cultivate 6-ft. rows without damage to the plant material, tractor, and, especially, the operator.

Our spacing is a 6-ft. wide row, with in-row spacing of 3 ft. and 4 ft. depending upon cultivar. We plant five rows and skip a row for access with digging and spraying equipment. This spacing gives us 1,500 plants per acre with 4-ft. centers and 2,000 plants per acre with 3-ft. centers.

Windmill's experience is we only have 60 to 70% plantable land in a given block of acreage. Terraces, turn rows, access roads, ponds, waterways, and fence rows take a much greater area than we first thought.

These ideas have helped us, and we feel B&B production still has an important place in the nursery industry.

PLANT PRODUCTION USING A ROOT CONTROL FABRIC CONTAINER

CHRIS THREADGILL

Forrest Keeling Nursery
Elsberry, Missouri 63343

Root Control fabric containers offer many advantages over the traditional methods of producing specimen-size trees; these include: 1) ease of harvest, 2) extension of harvest season, 3) elimination of expensive harvest equipment, 4) utilization of unskilled labor, 5) use of higher plant densities, and 6) improved survival.

Root Control fabric containers evolved from an idea of Dr. Carl Whitcomb, Stillwater, Oklahoma. The objectives were to devise a system of growing that would allow for quick harvest of specimen trees, build a superior root system and be simple to operate.

In 1980, after learning of Dr. Whitcomb's idea, Ralph Reiger of Oklahoma City, Oklahoma, had fabric containers made from a spun-bonded fabric material. The fabric containers' measurements were 16-in., 18-in., and 22-in. in diameter, with an 18-in. height and a fabric bottom. After some of the trees were harvested two years later, it was apparent that the fabric bottom was not necessary and complicated harvest. It was subsequently replaced with a disk of heavy polyethylene.

Girdling of each root where it grows through the fabric is the factor that makes plant production in Root Control fabric containers significantly better than the classical means of producing specimen trees. This should not be confused with spiraling roots, which occur in rigid containers above ground.

Root girdling occurs every time roots grow out and through the fabric container. Small roots have no difficulty penetrating the fabric container. As the root begins to enlarge in diameter, the fabric restricts the root. This restriction or girdling brings forth the advantages of the Root Control fabric container.

The restriction is never complete. Absorbed nutrients and water from outside the fabric container still move in, just as a small amount of carbohydrates manufactured by the plant can move out. Because of restriction at the fabric interface, flow both ways is reduced and accumulation occurs, especially on the inside of the fabric container.

The plant's root system responds to the girdling in a desirable way. Additional roots initiated within the fabric container are eventually girdled, resulting in additional root formation and an extremely fibrous root system.

The ability to harvest plants grown in fabric containers quickly is due to root girdling as well as to the fact that the plant's roots are

already "packaged". The harvester simply inserts a standard balling spade outside the fabric container and cuts the roots the entire depth of the container. Root Control fabric containers have a polyethylene bottom, so once all the lateral roots have been cut, the harvester simply pulls the plant up by the trunk of the tree. Average time to dig on a per man, per plant basis, is five minutes; thus the objective of rapid harvest is realized.

The ability to extend the harvest season was not considered while developing the fabric container system, although this is one of the major advantages of the system.

On August 3, 1982, nine trees (three *Betula nigra*, three *Pinus taeda*, and three *Fraxinus pennsylvanica*) grown in fabric containers for two years were dug and transported to the Oklahoma State University Nursery Research Station to evaluate their response to this season of harvest. All plants had stem calipers of about 2½ in. The following day the fabric containers were removed and the trees were planted. All trees were watered-in thoroughly, and received an additional inch per week when Mother Nature did not provide. It is important to note that temperatures exceeded 100°F both days, with 10 to 20 mph southwest winds. All trees survived and grew well. Only one river birch dropped 5 to 10 percent of its foliage. Seven weeks later, one of the river birch was redug and the root system evaluated. New root growth in excess of 16 in. was observed. It was possible to grow a 6-ft. Aleppo pine, *Pinus halepensis*, from a liner in less than two years.

This rapid regeneration of roots from the girdled root allows an extended harvest season. The plant, once harvested, does not have to heal large cut roots first, and then generate new roots, as is the case with classical methods of production and harvest. The fabric container-grown tree's roots are, in a sense, already healed and in a condition to produce new roots immediately.

Do not confuse the terminology used. Root girdling is an undesirable condition, whereas these are girdled roots. It is girdled roots that provide the merits of the fabric container.

We follow the same routine in land preparation for the fabric container production as we do for the rest of our field-grown plants. We feel there is no substitute for raw chicken litter incorporated into the soil followed by a crop of sudan grass, which is then turned under. However, I feel one would have satisfactory results with any decent soil.

We space plants 4 feet apart in the row with 8 feet between rows, which gives us a plant density of 1361 trees per acre. A fiberglass cylinder is slipped inside of the container before it is placed in the planting hole. The cylinder keeps the bag open while it is being filled and slips out easily once the soil has been added. The bags we are using are 16-in. tall. Larger sizes are available but are much harder to harvest because of added weight.

It is extremely important not to cover the top of the bag with soil as the fabric above the soil is what you must use to harvest the plant. We leave a 1½-in. collar. We can easily drill 950 planting holes a day, which makes the system very efficient. Our cost for planting 25,000 ft. of trees is about $10,500.

It takes us only 3 min. to harvest a 6-ft. pine. We remove about one inch of the soil, then fold the edges of the bag over the top and wrap the ball with twine. We ship only within a 50-mile radius but have not seen any indication that shipping would be a problem. We leave the plants upright and seem not to lose soil.

Although some nurserymen run a knife around the inside of the bag to help loosen the plant when removing the bag, it really isn't necessary. The knife doesn't cut the roots, just pops them loose. The roots are already girdled and do not need to be cut.

THE NURSERY INDUSTRY: WHERE ARE WE HEADED?

R. J. HUTTON

The Conard-Pyle Company-
West Grove, Pennsylvania 19390

GENERAL

Now that the rose is officially the floral emblem of the United States, I can say the nursery industry certainly has a rosy outlook!

I foresee a strong and growing demand for our products and services. In this I include all ornamental horticulture and floriculture. We are gaining more and more appreciation of and desire for all that plants and flowers can do for us in our daily lives both indoors and outdoors. Horticulturally, we are beginning to be a developed country.

I don't pretend to know what the future holds for our industry or any other. However, I can see the changes that have taken place in the years I have been a part of the nursery industry and can see the signs of future changes, which are likely to be much more dramatic on a year-by-year basis. These include:

1. **Computers.** Production operations as well as office administration and management functions will be computerized.
2. **Plant Growth Modeling.** Better sensors are being developed and programs written that will make modeling commonplace.
3. **Mechanization.** Go to any of the major trade shows like SNA, TANMISSLARK, AAN, BPI, and others that attract

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growers and look at the impressive equipment on display.

4. **Marketing.** Consumer tastes are changing and becoming much more segmented.
5. **Biological R & D.** This type of research is still in its infancy and devoted primarily to more economically-important agricultural crops for food and fiber.
6. **Resources.** Natural and other. What about energy costs, water availability for production and consumers? Labor availability?
7. **Government.** What will it do for us—and perhaps to us?
8. **Management.** Who, how? Can we as independent business people survive? You bet we can—and will.
9. **Information.** How are we going to find out what we need to know? With difficulty!

Our future is dependent entirely upon us. Everything we sell and buy is market-driven. If the market wants one of an item it may cost $1,000, while if the market is for 100, the price may well fall to $100. So we, as an industry, can become mechanized and automated if the equipment can be developed at a cost we can afford.

Which of these factors will be most important and the greatest influence on where we are headed? Most of us will differ in how we see these factors. Unfortunately, many nurserymen put marketing at the bottom of the list. I put it at the top! Why?

1. *None of us can exist without a market for our products or services.* Marketing is not selling. Marketing is developing a demand for a product.
2. *We are fortunate to have a product that most everyone wants, but it is not a daily necessity like food, fiber, and shelter.* That is a marketing advantage.
3. *Markets are changing.* Those of you who go back 30 years know that most nursery stock was sold by mail-order firms and sales agents who were the nursery counterpart to the Avon Lady. Then came local retail nursery stores; farm stands; and stores like Sears, Wards, and Woolworth during the late 50's and 60's. Now the mass retailers are leaving and nursery-garden center chains such as Franks, Wolfe, Nurseryland, and the "Home Center" retailers are coming into the plant business fast and will have significant impact. We hope that impact will broaden the market and availability of landscape plants.
4. *The market is becoming segmented.* Many of our customers are becoming more sophisticated and want a wider range of plants and services. This is especially true of two-income families.

5. *There is a native plant "fad".* I choose that word because I feel it is a fad. Granted the interest in native plants will be permanent, it will be at a level well below the peak we should reach in the early 90's. Xerophytic natives will be *more important, especially in arid regions.*
6. *We must become better marketers.* We cannot be just better sales people, because competitors among all products and services will be keener and more sophisticated. This is all the more reason we will need groups like the Nursery Marketing Council to carry our message to consumers. What we cannot do alone we must join together, financially, to do together. So far NMC is the most effective tool we have—support it and use it.

RESOURCES

Next in my order of priorities are resources. Energy is without question still a factor and will be, in varying importance, for all time to come. Here we have a marketing advantage when our products are used for climate control. But we are also going to suffer the burden of future energy shortages and unpredictable cost fluctuations.

My greatest concern relative to natural resources is water! In many, if not all, areas both availability and quality will become *increasingly critical. You people in Oklahoma and surrounding* states may question this now, but we along the mid-Atlantic and south Atlantic states do not.

When the water crisis hits, it will make the energy crisis of the recent past look like nothing. Stop and think what impact that will have on our production and sales because no amount of marketing will overcome a water shortage.

You should begin to think in terms of recycling runoff if you aren't doing so. It is going to cost, but it may mean staying in business.

Another resource which is going to be less available is labor. And, it will be more costly. As our population ages and as people reject menial hand work, we are headed for mechanization and automation. Labor efficiency and productivity are going to be essential. This is more apparent when you realize that service industries may be especially hard-pressed to come up with needed labor.

GOVERNMENT

Perhaps that heading should be plural. Government includes laws, regulations and their interpretation whether IRS, OSHA, EPA, ZONING, or even FCC, which may tune out your radio or increase your phone bill.

The so-called tax reform bill is just one example of what lies ahead in unknowns. Petty rules and loopholes will come out of it that will take two to three years to correct. However, I see benefit from this tax legislation in modifying tax shelters so that there should be less speculation and *frivolous* investment in nursery production. We can't afford the overproduction of the recent past even if we do not suffer a shrinking market caused by high interest rates that shut down new construction, remodeling of homes, or upward mobility in home buying.

An increase in the minimum wage will affect everyone because it moves right up the ladder to top management and will affect profit before prices reflect the change. And there goes inflation!

The new immigration reform will complicate our business lives. It makes us all law enforcers—policemen—to check the citizenship of each employee.

As a benefit we may get occasional zoning laws to prescribe landscape plantings with all new construction. Certainly plantings are needed from an environmental and esthic standpoint.

AUTOMATION AND MECHANIZATION

The likelihood of labor shortage puts a higher priority on mechanization. What are we seeing?

A. Canning/potting machines of increasing sophistication.

B. Mixers to customize media for crops and ever-improved blending of ingredients with better formula control.

C. Flat/tray filling equipment and all kinds of seeders for the bedding plant growers.

D. Greenhouse mechanization; including roller benches, mechanical watering, mechanical pesticide and nutrient application, energy-conserving curtains, light control.

E. Agrimation and agrobots are two terms which have recently appeared in both the trade press and popular press. This is the computerization of mechanization. Robots are programmable *automation*. They are computer controlled; hence, can be programmed to do different jobs and modified for different crops.

F. Sensors. The key to successful automation of our industry, or any industry, is sensors that give complete information, which can be interpreted and the needed action implemented.

G. And with all this will be better sanitation practices which will give higher yields of better quality plants resulting in more profit and lower costs to aid marketing.

BIOLOGICAL RESEARCH AND DEVELOPMENT

If we are in the infancy of computer development of our industry, we are still in the gestation period of biological developments.

We are all well acquainted with tissue culture; and as with computers, we do not know just how it may apply to many aspects of our needs, but I do not foresee that tissue culture will take over the propagation and multiplication of plants. I do see its importance in maintaining the gene pool of certain plant genera as already demonstrated. Basically, it will become a tool for building initial stock of new cultivars, cleaning up certain disease and pest problems for mother stock, cleaning up and truing up cultivars that have become widely varied and truing up cultivars for use in conventional plant breeding.

INFORMATION

The problems and possibilities of gathering, cataloging, and assimilating information in and for our daily business operations is only starting to be real to us. The proliferation of information today is incomprehensible. There is a doubling of literature, in our industry, every 6 years. Research indicates that the average business manager spends 3 to 4 hours a day reading just to *keep up* with the information needed to do his/her job. *Business Week* predicts that in 10 years the average manager will need 10 times more information—just to be informed.

How are we to cope *and* benefit *and* use this information? Computer data banks and information centers will come into play. Trade associations will sift it and condense it as a member service. Other publications will become available extracting the heart of the information.

MANAGEMENT

What has management to do with *The Future of Our Industry*? Management has to put this all together and make it work! *And* it must work at a profit. Management is making the *right* decision at the right time. Management is acquiring *access* to all the tools of the trade you can—then putting these tools to work.

CONCLUSIONS: (From: Greenhouse Grower Magazine—September, 1986)

"What of the Future? Why is high-tech mechanization necessary? For American products to be competitive internationally, the unit cost of labor plus mechanization must be comparable to foreign rates. Since labor accounts for 30 to 50% of current U.S. production costs, an increase in productivity achieved through high-tech mechanization could substantially improve profits in the green-

house industry.

"The nursery of the future will be an important component of profitable diversified agricultural production systems providing fresh, locally grown flowers, decorative plants, and vegetables at competitive prices (1).

LITERATURE CITED

1. Kutz, L. J., G. E. Miles, G. W. Krutz and P. A. Hammer. 1986. Robots in the Greenhouse. *Greenhouse Grower* 4(9):14–17.

MARKETING NURSERY CROPS

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Marketing is defined in various ways, but I will define it as the process of promoting sales and presenting the value and use of a product to potential consumers. It sounds simple enough. Everyone is deluged with a vast assortment of marketing ploys every day on television, radio, through newspapers, magazines, and billboards. Many of the products we buy are designed to enhance marketing of the same product in the future. Repeat purchases are encouraged by labels, colors, designs, and other information that we see every time we use the product. The toothpaste you use every morning is in a brightly-colored container to remind you of the brand you purchased and to increase the likelihood of getting you to purchase it again. The manufacturer of the toothpaste advertises it in an assortment of ways to try to retain you as a customer, but you must make your purchase at a local outlet.

Contrast these techniques with the practices most used in the nursery business. The wholesale grower produces a dynamic, attractive, growing and useful product and sells it to a retail nurseryman, garden center operator, or landscape contractor. Once the plants leave the wholesale nursery, little or no further thought, planning, or promotion of the product occurs. In essence, the wholesale nurseryman is turning over the future of the product entirely to the purchaser. In the past, the purchasers eventually came back and made additional purchases, so it was assumed that all was well.

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[1]Research Horticulturist

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The nursery industry creates an assortment of attractive, useful, interesting, intriguing, imaginative, colorful, fruitful, energy-conserving, privacy-enhancing, shade-providing, dynamic products that *increase* in value with time and generally function for many years. Who else offers a product that increases in value? Maybe a stockbroker if the consumer is lucky, but there is moderate to substantial risk. If the various trees and shrubs are selected carefully to fit the site, planted properly and given reasonable care, an increase in value of the nursery product as well as the surrounding buildings and grounds is nearly assured. Yet the consuming public purchases clothes, appliances, automobiles, and a myriad of other products worth billions and billions of dollars that drastically decrease in value as soon as the transaction is completed. If the nursery product is so dynamic and generally increases in value, why is it 10 laps behind in the race for the consumer's dollars?

I believe the answer lies in the marketing techniques used. Does the manufacturer of Crest toothpaste sell his product to the grocer, discount or drug store in your neighborhood unidentified as to its origin, function, and effectiveness and leave it up to the local retailer to market the product? Does General Motors sell the local Chevrolet dealer new cars with no further input or aid in marketing *those vehicles? Certainly not! Does McDonald's sell you a* hamburger so that the next time you want a hamburger you go to *any* store that sells a hamburger? They sell you a Big Mac, not a hamburger, and where can you get another Big Mac? Only at McDonald's!

I do not know of anyone in the wholesale nursery industry, at the present time, that is effectively marketing their products to the *consumer. They sell only to the intermediary and ignore any respon*sibility to market their product further. Most of the larger nurseries do tag their plants as to name, using a tag with the wholesale nursery logo, but is this of any value in the marketing of the product to the consumer? Very little. Since the consumer has never heard of B-Bob Wholesale Nursery, there is no tie, identity, association, or allegiance. And what was the name of that new plant just off the patio that is growing so well and has such beautiful flowers? "I am sorry, Neighbor Smith, but I just cannot remember, and the tag is lost or no longer legible. Maybe the fellow at Q-tip Garden Center will remember if you describe it to him." Slim chance! The customer is delighted with the product and would share with others if only the product could be identified. Why does your car say Chevrolet on the hood, trunk and dash as well as the specific model of Chevrolet on several locations? In addition, a fairly detailed booklet came with this product of declining value when it was originally purchased. An unfair analogy? Then what about that tube of toothpaste you use every morning, or the razor, or the can of coffee, or. . . . ?

If nursery markets are to expand, I feel there are several steps that must be taken:

1. The wholesale producer must become involved in marketing the product beyond the intermediate retail nursery, garden center, or landscape contractor. The Nursery Marketing Council is fine, but promotion needs to be more specific and localized.

2. Attractive labels that carry key information about the product must be attached to the product at the wholesale or producer level. These labels should be sufficiently durable to remain legible and attractive for the life of the product. You can still read "Crest" when the toothpaste tube is empty.

3. A recognition or identity must be established, creating a link between consumer and producer through the intermediary retail nursery or garden center, to create an allegiance. A wholesale nursery of any size can do this effectively with some imagination and effort.

4. The wholesale nursery must promote its new, more adaptable, larger products to the consumer. Effective promotion will create demand from consumer to intermediate retail nursery or garden center and back to the wholesale nursery. Do you think that Ford would leave to the local dealer the promotion of the new LTD super grand brougham with landau roof, opera windows, radially-tuned suspension and a new fuel-injected engine that is so much fun to own and drive that you simply *must* have one? Never!

Using the producer to retailer to consumer technique, new species or cultivars of trees or shrubs can be introduced quickly and effectively. The wholesale nursery has resisted growing any new species or cultivars for years because, "We cannot get the retail nurseries to buy them." The flip side of the record is also frequently heard at the retail nurseries and garden centers, "We can't get the wholesale nurseries to grow them."

The consuming public is interested in new plants but is continually fed the same old diet because of poor marketing techniques. If a wholesale nursery, or group of nurseries, grew a sizable quantity of a new cultivar and, in cooperation with the retail nurseries and garden centers in a region, promoted the unique qualities of this new introduction to the general public, an immediate demand would be created. If the retail nurseries and garden centers do not want to cooperate in the venture, the wholesale nurseries should do it alone.

I am not proposing that a wholesale nursery immediately go into the retail business as I feel you can do only one thing well. Rather, the nursery should create a demand for its product at the retail level. If consumers ask for a new product by name and it is possible for the retail nurseryman to get it, he will, and quickly. If the product is good and the customer is satisfied and returns to the retail nursery, the process is enhanced. On the other hand, if the

wholesale nursery promotes a new plant or cultivar with little or no testing and the new product performs poorly, the retail nursery will be hesitant to participate in the future. High quality products are essential if the system is to work.

5. The interest in horticultural products in general and landscape plants in particular is tremendous. The better the product, the greater the demand. When speaking to non-horticultural groups about various plants, invariably someone laments, "I planted one of those once and it died." To some degree they are "turned off" to buying more because the product did not perform as expected.

Perhaps the wholesale nursery should share some responsibility with the retail nursery or garden center if the product does not perform. There is a clear relationship between techniques used in producing the product and how it performs. Sears did not get to be the number one retailer of merchandise by saying, "sorry", when a product performs poorly. A satisfied customer is relatively quiet, but a dissatisfied customer shares his experience far and wide.

The pessimist notes, "If every plant lived, the market would soon be saturated." My position is just the reverse—if nursery products consistently performed well, almost in spite of the actions of the retailer or consumer, there would be much more interest and willingness to add more or make replacements. We must accentuate the positive, "sell the sizzle", and enhance the image and quality of nursery products in the eyes of the consumer. This can only be done through effective marketing.

DETERMINING CONTAINER PRODUCTION COSTS ON A PER PLANT BASIS

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Nurserymen are businessmen. Like all businessmen our main objective must be to make money, a profit over and above our expenses. No business can survive without making a profit.

There are several ways of accessing the profitability of a business. Some monitor bank accounts; others produce periodic income and expense statements. Johnson Nursery is concerned about the profitability of every plant. It is the sale of plants that produces income for this business. If the nursery is going to be profitable, the plants we sell must be profitable. To determine this degree of profitability we have developed a method of cost allocation in which all expenses incurred in the nursery are allocated to all plants.

Before discussing the cost allocation procedure, examine Table 1; this is the end result. The table lists the various container sizes we grow, separates the containers according to the size plant from which they were potted, and shows the cumulative expense allocated to each size over 18 months. For example, a three-gallon plant grown from a one quart liner (3G-QT) that has been in production for nine months, has cost the nursery $3.17. In like manner, other production costs can be determined for the other sizes at various ages.

The remainder of this paper provides explanation of how figures in Table 1 were developed.

The first step in allocating expenses is to determine the expenses. Table 2 is the expense portion of an income statement for the month of July. These expenses, except freight sales, are allocated to all plants in the nursery. Although Johnson Nursery delivers about 90% of its sales, freight is a service to our customer and not a means of making money. Therefore, freight expense is

Table 1. Cost Per Plant Analysis,[1] July, 1986.

	CONTAINER SIZE								
Months	QT-BR	1G-BR	1G-QT	2G-QT	2G-1G	3G-QT	3G-1G	7G-2G	7G-3G
1	0.28	0.50	0.81	1.03	1.82	1.31	2.05	4.16	4.78
2	0.31	0.58	0.94	1.14	1.83	1.47	2.20	4.47	5.09
3	0.37	0.68	1.05	1.30	2.00	1.75	2.48	4.88	5.50
4	0.41	0.78	1.15	1.45	2.14	1.99	2.72	5.30	5.92
5	0.45	0.86	1.23	1.58	2.27	2.20	2.93	5.66	6.28
6	0.49	0.95	1.32	1.71	2.40	2.42	3.15	6.03	6.65
7	0.53	1.04	1.41	1.85	2.54	2.65	3.38	6.43	7.05
8	0.59	1.25	1.62	2.05	2.74	2.99	3.72	7.02	7.64
9	0.62	1.32	1.69	2.16	2.85	3.17	3.90	7.32	7.94
10	0.67	1.42	1.79	2.31	3.01	3.42	4.15	7.76	8.38
11	0.72	1.51	1.88	2.45	3.14	3.64	4.37	8.14	8.76
12	1.02	1.86	2.23	2.71	3.40	4.11	4.84	8.50	9.12
13	1.05	1.93	2.30	2.82	3.51	4.29	5.02	8.81	9.43
14	1.08	2.02	2.38	2.95	3.64	4.50	5.23	9.17	9.79
15	1.13	2.11	2.48	3.09	3.79	4.74	5.48	9.59	10.21
16	1.17	2.21	2.58	3.24	3.93	4.98	5.71	10.00	10.62
17	1.22	2.32	2.69	3.41	4.10	5.27	6.00	10.50	11.12
18	1.27	2.40	2.77	3.53	4.22	5.46	6.19	10.83	11.45

[1] Months represent the length of time the plant has been in production. The top of the columns gives the size container and the size container from which it was grown. For example 3G-QT represents a three-gallon grown from a quart. The table lists the expense that has been allocated to the various size plants at different stages of production. For example, a two gallon grown from a quart (2G-QT) that has been in production for nine months has an expense of $2.16.

Table 2. Expense statement for July, 1986.

Operating Expenses:

Salaries	$ 6,543	General supplies	0
F.I.C.A.	487	Tools	25
Nursery Supplies	10,048	Rep. & main.	785
Interest	2,343	Lic. & taxes	0
Depreciation	1,800	Membership dues	0
Attorney	0	Literature	0
Accountant	0	N.C. sales taxes	64
Insurance	502	Travel	0
Telephone	245	Advertisement	54
Utility	252	Service charge	0
Office supplies	79	Postage	69
Freight, purchase	485	Entertainment	10
Freight, sales	1,262	Miscellaneous	0
		Total Operating Expense:	$25,052

offset by freight income and is not allocated to the cost of plant production. All other expenses are allocated.

In producing plants, as much as one-third of the expense is incurred during the first day of production. These expenses are classified as initial production costs. Space will not permit a lengthy discussion of how initial production costs are determined; how-

ever, a summary of these expenses are found in Table 3. These expenses will not change with an increase in production on a per plant basis. For example, to grow 1000 additional three-gallon plants requires 1000 additional pots at $0.2730 per pot.

Table 3. Initial production costs.

	QT-BR	1G-BR	1G-QT	2G-QT	2G-1G	3G-QT	3G-1G	7G-2G	7G-3G
Liner	0.1500	0.2500	0.5500	0.5500	1.3400	0.5500	1.3400	2.4900	3.1900
Container	0.0400	0.0800	0.0800	0.1850	0.1850	0.2730	0.2730	0.7900	0.7400
Labor	0.0431	0.0606	0.0750	0.1031	0.1500	0.1337	0.1500	0.2750	0.3850
Pot media	0.0188	0.0496	0.0435	0.0950	0.0496	0.1982	0.1333	0.3304	0.1900
Total	0.2519	0.4402	0.7485	0.9331	1.7246	1.1549	1.8963	3.8854	4.5050

Unfortunately the investment does not stop here. A plant remains in production until sold. Each month we pay for chemicals, fertilizer, supplies, telephone, utilities, insurance, repairs and other overhead items. These expenses, referred to as "monthly recurring expenses", are independent of the inventory. Our phone bill is not directly proportional to the inventory, neither is the attorney's fee, nor interest expense. Nevertheless, it is the sale of plants that will pay for these expenses. If our plants are profitable, we must sell them at a price that exceeds that incurred from these expenses.

We must have a list of these expenses in order to allocate amounts. This requires excellent record keeping. First, labor allocation will be discussed (Table 4). The activities of each employee are recorded each day, and at the end of each month these daily labor sheets are compiled into a labor allocation table. Some of these expenses (potting labor, propagation labor, and soil mixing) are part of initial production costs and are allocated to either potting labor, liner or potting media expense. Management and secretary expense are allocated directly as monthly recurring expenses. The remainder of these labor expenses are allocated as recurring production costs. These include all other labor expenses such as pruning, spraying, fertilizing, and even such expenses as vacation pay.

Table 4. Labor allocation.

Manager	$1,664
Office	340
Recurring production costs	1,921
Initial production costs	2,618
Total	6,543

The next category of expenses is nursery supplies, which totaled $10,048 for July, 1986 (Table 2). Many of these expenses, such as containers, potting media, and liners went into the plants

the first day of production. These expenses are classified as initial production costs. Recurring production costs are incurred while the plants are in production. These expenses, such as fertilizers, insecticides, and herbicides are used in the plants' growth, maintenance, and production. Table 5 separates the initial production costs and recurring production costs for nursery supply expense.

Table 5. Nursery supply allocation.

Initial production costs	$ 8,843
Recurring production costs	1,205
Total	10,048

Most major expenses in Table 2 are allocated as shown (interest and depreciation) or have previously been discussed (salaries and nursery supplies). Operating expenses, such as insurance, phone, and utilities are aggregated into general overhead.

Table 6 summarizes all of the expenses that are to be allocated as monthly recurring expenses. These are to be allocated to all plants in the nursery. Although some accountants argue that it is incorrect to allocate interest and overhead to production costs, we disagree. The only way Johnson Nursery can pay our bills is through plant sales. If our sales price per plant is not high enough to cover all expenses, the business will not realize a profit.

Table 6. Monthly recurring expenses.[1]

Labor expenses	
Management	$1.664
Office	340
Production	1,828
Interest	2,343
General overhead	3,057
Nursery supplies	1,205
Depreciation	1,800

[1]These are the expenses that will be allocated to the plants for the month of July.

We must have an accurate inventory of the number of plants in the nursery in order to allocate monthly expenses in this way. Keeping accurate inventory records in any nursery is difficult, at best. To overcome this problem, we maintain daily records of the number potted and monthly records of the number sold or thrown away. This inventory count is periodically checked against the number of plants actually in the nursery. Table 7 lists the inventory as of July 1, 1986.

The next step is to allocate expenses over items that do not have the same market value. It would be inaccurate to allocate the same amount of interest expense to both quart and 7-gallon containers. Therefore, a standard allocation unit (AU) was derived to compare different sizes according to their ease of handling and the growing

Table 7. Inventory, July 31, 1986.

No. of quarts	37367
No. of gallons	61190
No. of 2 gallons	20076
No. of 3 gallons	32557
No. of 7 gallons	564

area they require (Table 8). These values are used to allocate the recurring expenses to the various container sizes. For example, a quart is given a value of 1(AU), while a one gallon is 2.3(AU). This means that a one-gallon will be allocated 2.3 times more expense than a quart. A three-gallon will receive 5.8 times more of a given expense than a quart and about 2.5 times more expense than a one-gallon. The following example may help explain this concept. If $22.60 of expenses were to be allocated over five containers, one of each size, it would be allocated in the following manner: Quarts = $1.00, one gallons = $2.30, two gallons = $3.50, three gallons = $5.80, seven gallons = $10.00. If $22.60 of expense were to be allocated over 10 containers, two of each size, the above costs per would be cut in half. For example, quarts would be allocated $0.50 expense.

Table 8. Allocation values.

Allocation units	
Quart =	1.0 (AU)
1 gal =	2.3 (AU)
2 gal =	3.5 (AU)
3 gal =	5.8 (AU)
7 gal =	10.0 (AU)

With this system a quart receives one unit (1AU) of allocation value. Johnson Nursery has 7,367 quarts in inventory; therefore, quarts have a total value of 37,367 allocation units (37,367 × 1). In like manner the allocation value of two-, three- or seven-gallons can be determined from Table 9.

Table 9. Allocation units (AU).

37,367	qts ×	1.0 (AU per qt)	=	37,367 (AU)
61,190	1 gal ×	2.3 (AU per 1 gal)	=	140,737 (AU)
20,067	2 gal ×	3.5 (AU per 2 gal)	=	70,266 (AU)
32,557	3 gal ×	5.8 (AU per 3 gal)	=	188,830 (AU)
564	7 gal ×	10.0 (AU per 7 gal)	=	5,640 (AU)
		Total allocation units	=	442,840 (AU)

The inventory, as seen in Table 9, has a total value of 442,840 allocation units. Interest is allocated to the inventory by dividing interest expense ($2,343) by total allocation units (442,840). This reveals that one allocation unit has an interest allocation value of $0.0053. In like manner, the value of one allocation unit for each

recurring expense is computed in Table 10.

Table 10. Allocation unit expense.

	Monthly expense		Value of one allocation unit (AU)
Management	$1,664	divided by 442,840 =	0.0038
Office	340	divided by 442,840 =	0.0008
Production	1,828	divided by 442,840 =	0.0041
Interest	2,343	divided by 442,840 =	0.0053
General overhead	3,057	divided by 442,840 =	0.0069
Nursery supplies	1,205	divided by 442,840 =	0.0027
Depreciation	1,800	divided by 442,840 =	0.0041

It is now possible to allocate the recurring monthly expenses to all plants. A quart has an allocation value of 1(AU). Table 10 shows that 1(AU) of interest expense is valued at $0.0053; therefore a quart receives $0.0053 of interest expense (0.0053 × 1). A gallon has an allocation value of 2.3 (AU) so it has an interest expense value of $0.0122 (2.3 × 0.0053). In like manner, the interest expense allocation for two-, three- and seven-gallons can be determined, and is found in Table 11.

The results of allocating all of the monthly expenses to all of the plants and the total allocation to each plant is seen in Table 11. Each month will vary due to changes in inventory and expense.

Table 11. Allocation of monthly recurring expenses for July.[1]

	Manage. Cost/plt	Office Cost/plt	Produc. Cost/plt	Interest Cost/plt	Overhead Cost/plt	Nur. supp Cost/plt	Deprec. Cost/plt
Quart = 1.0 (AU) =	0.0038	0.0008	0.0041	0.0053	0.0069	0.0027	0.0041
1 Gal = 2.3 (AU) =	0.0086	0.0018	0.0095	0.0122	0.0159	0.0063	0.0093
2 Gal = 3.5 (AU) =	0.0131	0.0027	0.0144	0.0185	0.0242	0.0095	0.0142
3 Gal = 5.8 (AU) =	0.0218	0.0045	0.0239	0.0307	0.0400	0.0158	0.0236
7 Gal = 10. (AU) =	0.0376	0.0077	0.0413	0.0529	0.0690	0.0272	0.0406

[1]This table lists the allocation expense for each size container with regard to each category of expense.

Now back to the beginning, Table 1. The expenses allocated to plants potted in July can be found on the first line (month 1). Two-gallon containers potted from quarts have an expense of $1.03. This results from adding the initial production cost for July ($0.9331 from Table 3) plus monthly recurring expense for July ($0.0967 from Table 11). Two-gallon containers that have been in inventory for 10 months have a total expense of $2.31 (initial production cost for September, 1985 plus all recurring expenses from September through July, 1986). In like manner, all other expenses for different sizes and ages can be determined.

The relevance of the costs presented in this study to other nurseries is questionable. Size of inventory, efficiency of operation, degree of indebtedness, among other things, would affect the overall cost per plant. However, a similar procedure could be developed to fit any nursery. The information this ongoing study gives Johnson Nursery is significant. We know our time limitations for growing plants. Discounts can easily be decided upon with regard to profitability. This study will also reveal production efficiency increases and decreases.

ROOT STRESS IN CONTAINERS

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Plants that are container-grown in artificial media are subjected to many stresses different from those encountered by a plant grown in soil. Containerized root systems are confined to a limited volume; thus, they rely on supplemental irrigation, supplemental nutrition, and are not buffered against temperature changes. Containers are left above ground during the winter, exposing the roots to temperature extremes. Roots are not as hardy as shoots; therefore, roots may be injured at temperatures lower than those that injure shoots (15). Summer container-media temperatures, in contrast, can easily exceed temperatures considered optimum for good root growth (14).

Container plant production of woody ornamentals has expanded rapidly in recent years and now represents more than 50 percent of all landscape plants sold in the United States (15). Technological advances have, and are, revolutionizing the nursery industry. However, as growers are keenly aware, temperature extremes and devastating winter freezes can destroy a crop unless some protection is provided. The objectives of this paper are to discuss high and low temperature stress of roots in containers and describe the physiology of root temperature stress.

LOW TEMPERATURE ROOT STRESS

Cold hardiness varies among species and often varies among cultivars and ecotypes (10). Marked differences are also observed among tissues on the same plant (15). Reproductive buds are less

[1] Assistant Professor

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hardy than vegetative buds (10) and roots are less hardy than shoots (17). There are two forms of low temperature stress: freezing and chilling.

Freezing stress in containers. Freeze damage of roots occurs when ice forms within the tissues. Ice formation may be either extracellular or intracellular (11). When intracellular ice forms, crystals form within the protoplasm. Ice formation within the protoplasm tears membranes and is lethal (11). This type of ice formation occurs infrequently, and only when temperature falls very rapidly (15). Plants that are more resistant to intracellular freezing temperatures have protoplasts high in available water and few ice nucleators. This allows the protoplasm to *supercool* to temperatures as low as −30° to −47°C (−22° to −53°F) (10). Extracellular ice is ice that is formed between the cells and occurs during normal winters. Water that is within the cell moves outward towards the extracellular ice crystals in response to a vapor pressure gradient until an equilibrium exists (17). When too much water is removed by this means, damage may occur to the cells by desiccation (10).

Temperate woody plants acclimate, become hardy, to freezing temperatures in response to cooling temperatures and longer night periods (15). Freezing tissues for short periods also contributes to hardening (17). However, the hardening of roots is not as well understood as for shoots. Fall temperatures greater than 15°C (60°F) reduce root hardiness, thus cool temperatures contribute to root hardiness by slowing or stopping root growth (15). Variations in root hardiness do exist and the relative hardiness is known for many plants (Table 1).

Table 1. Average root killing temperatures (°F) of selected woody landscape plants [compiled by Smith and Beattie (15)].

	Studer[a]		Havis[b]
Taxon	Immature	Mature	All
Magnolia × *soulangeana*[c]			23
Buxus sempervirens	27		15
Cotoneaster microphyllus	25	9	
Ilex cornuta 'Dazzler'	25	18	
Pyracantha coccinea 'Lalandei'	25	18	18
Mahonia bealei	25	12	
Cotoneaster dammeri	23		
Euonymus fortunei var. vegeta	23	12	
Hypericum spp.	23	18	
Ilex crenata 'Helleri'	23		
Ilex 'Nellie Stevens'	23	14	
Ilex × *meserveae* 'Blue Boy'	23	9	
Ilex opaca	23	9	20
Cornus florida	21	11	20
Euonymus kiautschovica	21	16	
Ilex 'San Jose'	21	18	

Taxon	Studer[a]		Havis[b]
	Immature	Mature	All
Magnolia stellata	21	9	23
Daphne cneorum			20
Ilex crenata 'Convexa'			20
Ilex crenata 'Hetzii'			20
Ilex crenata 'Stokesii'			20
Leucothoe fontanesiana	19		5
Rhododendron prunifolium	19		
Viburnum plicatum forma *tomentosum*	19	7	
Rhododendron 'Hino-crimson'	19		
Cotoneaster dammeri 'Skogholmen'	19		
Euonymus alata 'Compacta'	19	7	
Cryptomeria japonica			16
Stephanandra incisa 'Crispa'	18	0	
Rhododendron (Exbury Hybrid)	18		
Taxus × *media* 'Hicksii'	18	−4	
Koelreuteria paniculata	16	−4	
Kalmia latifolia	16		
Pieris japonica	16		10
Rhododendron 'Purple Gem'	16		
Rhododendron schlippenbachii	16		
Cotoneaster horizontalis			15
Juniperus conferta	12	−10	
Juniperus horizontalis 'Plumosa'	12	−4	
Juniperus squamata 'Meyeri'	12		
Viburnum carlesii			15
Cytisus × *praecox*			15
Ilex glabra			15
Euonymus fortunei 'Carrierei'			15
Euonymus fortunei 'Graciles' [syn. *E. fortunei* 'Argenteo-marginata']			15
Hedera helix 'Baltica'			15
Pachysandra terminalis			15
Vinca minor			15
Pieris japonica 'Compacta'			15
Acer palmatum 'Atropurpureum'			14
Cotoneaster adpressa var. *praecox*			10
Taxus × *media* 'Nigra'			10
Rhododendron 'Gibraltar'			10
Rhododendron 'Hinodegiri'			10
Pieris floribunda			5
Euonymus fortunei 'Colorata'			5
Juniperus horizontalis			0
Juniperus horizontalis 'Douglasii'			0
Rhododendron carolinianum			0
Rhododendron catawbiense			0
Rhododendron (P. J. M. Hybrids)			−10
Potentilla fruticosa			−10
Picea glauca			−10
Picea omorika			−10

[a]Studer, E. J. *et al.* 1978.
[b]Havis, H. R. 1976.
[c]Differences in root-killing temperatures for the same taxa were most likely due to variations in root maturity and experimental procedure.

Chilling stress in containers. Chilling injury of plants occurs at temperatures several degrees higher than freezing (10). Chilling-sensitive plants primarily include species of tropical origin. Chilling-sensitive species generally suffer damage indirectly through desiccation. Desiccation injury occurs when water is lost from the plant to the atmosphere faster than it can be replaced through the roots (15). Often leaf and air temperatures are high and the ambient air has a low relative humidity during midwinter through early spring. The vapor pressure deficit from the plant to the air is high, which results in excessive moisture loss. Further injury can occur if water cannot move within the plant to replenish desiccated leaf and stem tissues (15).

The restriction of water movement through root systems at chilling temperatures causes wilting (13). Increased water viscosity at low media temperatures is responsible in part for the decrease in water transport. Markhart, *et al.* (12) demonstrated that chilling reduces flux of water through chilling-sensitive plants and that the changes in hydraulic conductance were greater than those accounted for by the increase in viscosity of water. The rate-limiting site for water movement through a root is a membrane (12). The membrane most likely responsible is at the endodermis where all apoplastic water transport (extracellular water) must enter the symplast (intracellular water) for vascular water transport from the roots to the shoots.

Root systems have been demonstrated to acclimate to low temperatures, becoming more resistant to chilling stress. A major difference between chilling-acclimated root tissue and non-acclimated tissue is the degree of fatty acid saturation. Roots that are grown at low temperatures, 8° to 10°C (46° to 50°F) have a greater abundance of unsaturated fats in their membranes compared to roots grown at 20°C (68°F) (2). This increase in unsaturation correlates with increased water transport through acclimated root systems (3). During acclimation to low temperatures, phosphorus incorporation into membranes occurs more rapidly at low media temperatures compared to high media temperatures (2). Thus, phosphorus nutrition is important for root hardiness.

HIGH-TEMPERATURE ROOT STRESS

High temperature root stress is an important concern of nursery growers, especially when the air temperature exceeds 35°C (95°F). It is at this temperature that summer dormancy of nursery plants occurs, and plants will not grow until the temperature is reduced (4). High media temperatures, a principal cause of summer dormancy, contributes to plant stress. This is termed high-temperature root stress.

Root damage occurs in a container nursery during midsum-

mer, with the southern and western exposures of containers and plots being most severe (5, 8, 14, 18, 19, 21). Temperatures as high as 50°C (122°F) have been reported (5, 14, 18, 19, 21). Roots either die or become weak on the exposed surfaces. The plant then becomes less thrifty and possibly dies (20). This is confounded after scheduled spacing if the original orientation of the container is not maintained.

Polyethylene containers are widely used because they are rigid and light enough for shipping, durable enough to withstand field handling, and fairly inexpensive (4). Black is the preferred color because it is cheaper to manufacture, causes media temperatures to increase rapidly stimulating earlier spring growth, and prevents algae growth and root greening.

Growing surfaces also contribute to root damage (14). For example, many nursery growers place their containers on either crushed limestone rock or white shells. These lightly colored materials are highly reflective and the resulting albedo increases the heat gain of a dark container (14, 19).

White containers have been shown to reduce media temperatures but such containers allow light transmission, contributing to root greening and algae growth (18). White polybags with black liners significantly reduce media temperatures and reduce light transmission (8, 18, 19). However, white polybags are not acceptable containers for a large scale container nursery because they are difficult to handle in the field and are difficult to ship with conventional equipment and techniques (8).

High temperature stress is defined as the retardation or cessation of metabolic functions in response to high temperatures. Temperature susceptibility varies among species and the vital metabolic process concerned (10). Alexandrov (1) described the first symptom to appear in response to heating was the cessation of protoplasmic streaming. Next, the rate of photosynthesis was decreased with subsequent damage to the chloroplasts. In the terminal stage, semipermeability of cell membranes was disrupted. Ingram (8) reported lethal temperatures for thermostability of root cells of several species from 45° to 50°C (113° to 112°F).

Little research has been devoted to root water uptake at high media temperatures. Kramer (9), using heat-killed root systems, demonstrated that plants remained alive and unwilted for several days after root death. Transpiration decreased after root death due to leaf injury and gum deposits released from dead cells.

Predawn shoot water potential of *Berberis thunbergii* 'Atropurpurea' and *Pittosporum tobira* 'Wheeler's Dwarf' increased when exposed to media temperatures greater than 40°C (104°F) (14). Predawn shoot water potential of *Buxus microphylla* var. *japonica* increased when exposed to media temperatures greater than 45°C (113°F) (14). These data correlated with increased hydraulic

conductance data, where hydraulic conductance of *B. microphylla* increased linearly from 25° to 45°C (77° to 113°F) and *B. thunbergii* increased quadratically over the same temperature range (14). Even though water was not limiting, stomatal conductance was decreased sharply due to toxic substances released into the transpiration stream.

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PRODUCTION TECHNIQUES TO MINIMIZE STRESS

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This paper summarizes the production techniques used at Greenleaf Nursery Company's Oklahoma Division to reduce plant stress from both high and low temperatures. The nursery is located in hardiness zone 6, based on average minimum temperature, and zone 4, based on extreme minimum temperature. We have had temperatures from −18°F to 112°F. We are constantly forced to deal with a wide range of temperatures. It is from this experience that we have developed these techniques.

COLD WEATHER STRESS REDUCTION

Many of our ideas regarding cold weather changed after the winter of 1983–84. The effects of those observations are included in this current list.

Proper hardening of plant material prior to the onset of cold weather. This factor is quite possibly the single most important factor in reducing plant stress and subsequent damage or death due to cold weather. We establish dates for different broad groups of plant materials, at which time we reduce the nitrogen level in the container and the amount of water applied to the plant. We also never wash off frost that accumulates on the plants in the fall in order to help harden the growth.

Structures. We currently use several types of poly houses for winter production.

1. Portable wooden 'A' frame structures.
2. Permanent welded pipe frame houses.
3. Commercial gutter-connected greenhouses.
4. Quonset-type structures.

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We currently have about 400,000 ft.^{2} under poly in the propagation area in both quonset-type and gutter-connected greenhouses. We will have over 1½ million ft.^{2} under poly in our container growing area. Most of that area is supported by wooden 'A' frame structures; however, some of the space is now in both welded pipe and commercial structures. Each type structure has its advantages and limitations. The structure we are currently trying to build is the welded pipe structure, since the maintenance and handling on the 'A' frames is so expensive, as is the initial cost on the commercial house.

Windbreaks. Windbreaks constructed from either taller, hardier, plants or from inert materials, such as plastic, have varying degrees of success in reducing stress. Generally speaking, we have not had good success using wind breaks where we only erected vertical barriers.

Mulching (or other types of insulation barriers). We continue to use a large amount of wheat straw to mulch our containerized 1 gal. and 5 gal. trees. This can be a problem-solver or problem-maker depending on the severity of the winter. The straw does provide good insulation and protection to the roots in moderate to hard winters, but in severe winters the medium in the containers can freeze solid under the straw. Once that happens, it is next to impossible to thaw the medium, due to the insulation the straw provides.

Bunching the containers. Grouping container material as tight as possible is one of the best methods of protection. Where young plants are still sitting can-tight, we will also fill the aisles between the beds, in order to create one solid block of plant material. When bunching containers, we also stagger the rows to create a tighter group. Depending on the cultivar, we may use hardier plants, straw, or microfoam around the perimeter of the bunched plants as a barrier.

Other factors.

1. Adjusting planting times so that you expose the crop to less winter, give it more time to harden off before winter, or change to spring planting.
2. Using square containers so that you create a tighter seal across the top of the bed of bunched plant material.
3. Use of metal cans. If it fits your scheme and your market, containerized plants have a greater survivability in metal cans than in plastic.
4. Not moving a container any more than is necessary right before the onset of cold winter. If the container has formed a seal with the ground and you break that seal and move it, the plant will have less chance of surviving a severe winter. (Honest, its true!)

Planting time. Be sure the plant is well established by the onset of hot weather. This allows the plant to develop a good root system and a natural shade canopy over those roots before it gets hot. This will make a tremendous difference in avoiding heat stress.

Shade cloth. We use both temporary shade and permanent pipe and cable shade structures with a number of cultivars. During the hottest summers, we have some cultivars that may require temporary shade over a two- or three-week period to cope with the temperature extremes. We use 47% shade over American arbor-vitae and 'Crimson King' maple, for example. We have disease developing if we use heavier shade.

Spacing. We always try to wait to space out a plant until it has a full canopy over the container and try not to space it out immediately after it has been sheared

During periods of extreme heat we have also filled the aisles with plants and put microfoam on the south and west edges of the block. This drastically reduces the exposure to high soil temperatures along edges of the bed that have a strong sun exposure. We have experienced soil temperatures of near 130°F on the edges of our beds in black poly containers.

Shearing. Not shearing at all on some cultivars when it gets very hot is one way to reduce stress. Some cultivars will appear to be growing quite lushly and apparently require shearing but will, in turn, stress very badly if sheared when the temperature is high.

Water application. We use a water tank mounted on a trailer to water the edges of the blocks when they dry out in the extreme heat. That way we do not have to apply the water to a whole block of containerized plant material when only the edges are stressed. We will also use a short period of overhead water during the day on some of our broadleaf and tree blocks to reduce stress and wilt. Then we can come back later in the day with a longer watering to wet the medium thoroughly.

This has been a quick overview of the subject of preventing cold and heat stress in containerized plant material. Our views on the subject tend to be in a constant state of revision with the experience we gain after each period of extreme stress.

SYRINGING TO REDUCE STRESS: IS IT EFFECTIVE?

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Obviously it can be. The use of water in the propagation of cuttings is a prime example. For propagation, a portion of the shoot is removed from the stock plant and placed in a favorable environment to encourage the development of roots. Until rooted, the cutting is subjected to various stresses, including water loss. As propagators we manipulate environmental and cultural conditions to minimize these stresses and promote rooting. One tool we use is water. We arrange the frequency and duration of its application to insure high humidity around the cutting while maintaining a film of water on the exposed plant tissue. We attempt to apply sufficient water to keep the foliage wet and the humidity high without actually irrigating or waterlogging the growth medium. How frequently and how much water we apply varies dramatically depending on the crop, location, time of year, propagation medium, and the water delivery system and its controls.

At Cottage Hill Nursery most cuttings are started out on a 10- to 15-minute misting frequency with a 10- to 12-second duration. We lengthen the frequency interval as rapidly as possible. We use a very coarse mist delivered by conventional impact-type sprinklers that are run in reverse. This system puts out a lot of water, which we are able to deal with because of the well-drained media that we use. The system works well under our conditions and allows us to propagate our plants in the same location and with the same irrigation system that we use during the production phase.

Regardless of specific details and variations, mist propagation is a very successful use of syringing to reduce stress. There are others.

Transplanting stress can be drastically reduced by intermittent syringing. With seedlings we typically use a 20- to 60-minute syringing frequency for the first few days after transplanting. Duration should be sufficient to wet the foliage without actually irrigating the medium. This cools the leaves and minimizes water loss until the seedlings can become established. The same program works well in any transplanting situation—rooted cuttings, bareroot liners and field dug plants, for example.

The benefits of syringing are greatly reduced once a plant becomes established. Established plants have sufficient roots for sustenance and growth, and water stress is dealt with by adequate irrigation; however, other stresses become significant, and appropriate water use can be very helpful.

High summer temperatures, particularly in the South, result in significant stress on container plants. At moderately high temperatures, plant metabolism particularly respiration, is elevated. More energy is expended than produced, which reduces growth. At higher temperatures some tissues, such as roots, cannot survive. Since root ball temperatures in containers may reach 120°F or higher, growth is frequently inhibited and roots are killed. Healthy, active roots are the key to successful container production; thus, reducing excessively high root-ball temperatures is beneficial.

The appropriate use of water is one means of reducing root-ball temperatures. Comparison of syringing and irrigation timing has demonstrated very little benefit from midsummer syringing of established container nursery stock. Hourly syringing reduced canopy temperatures, but not root-ball temperatures, and resulted in no growth difference; however, the time of day that the plants are irrigated is important. Irrigation during the heat of the day reduces root ball temperatures 7° to 13°F and increases plant growth.

On most nurseries irrigation demands require application throughout the day, which means optimum timing is impossible. However, midday irrigation of problem crops or crops that are being "pushed" can contribute to increased growth.

Avoiding cold injury is another place where water application can be utilized as a tool. One technique involves the "icing over" of a crop to protect it during severe cold. Some nurseries have coated their plants with a sheet of ice to insulate them. Unfortunately, ice is a very poor insulator and this practice usually results in increased damage due to low temperatures and tissue desiccation.

If plants are to "ice-over" successfully, water must be applied continuously. This results in sustained ice buildup with heat being released by the freezing water and insures a moist environment to prevent desiccation. Temperatures under the ice remain just above freezing. Using this method we have successfully overwintered indica azaleas, pittosporum, holly, boxwood, and other species when ambient temperature went to 3°F, with a wind chill well below zero.

Icing over is another situation where the method cannot be used for protection of an entire nursery, but it may be successfully employed over a limited area. One should be aware that although continuous icing is effective, damage can develop very rapidly if you lose the ability to apply water.

At the liner division of Cottage Hill Nursery we use water as the sole heating source in our greenhouses. We grow a wide range of woody-ornamental liners in quonset-style, single or double poly-covered structures. On cold nights we keep these houses above freezing by intermittent syringing.

We use cyclic timers or electronic controllers, typically set to syringe each house for 45 seconds every 10 minutes. Water tempera-

ture is about 65°F and we apply up to 1 in. of water per hour of "on" time, depending on sprinkler type and spacing. This means that from the water we apply intermittently we can obtain 50,000 BTU's of heat per hour as the water cools from 65°F to 32°F. If this amount of heat is insufficient to prevent subfreezing temperature, ice begins to form on the plastic film of the greenhouse interior walls. Freezing water releases considerable heat (80 calories/gram). So freezing continues until enough heat is released to raise the temperature to just above 32°F. We apply enough water each hour to provide a reserve in excess of 200,000 BTU's if all of it were to freeze.

For this system to work dependably we must have a reliable water source, be able to deliver the water with the necessary frequency and duration, and have backup capability both for power supply and pumps.

We use strategically placed temperature sensors to monitor the operation. These are located in the northwest corner of our most exposed houses between the outside row of plants and the inside greenhouse wall. We follow weather conditions closely, but as an extra precaution we employ a thermal alarm system which will alert personnel at home when conditions warrant attention.

This program has worked effectively for several years even when we have experienced low, single digit temperatures. A wide range of species including cold-sensitive crops and plants in active growth have been protected and protected economically using only intermittent syringing. With our well-drained growth medium and our relatively infrequent need to use the system, we have experienced no root deterioration or disease problems.

However we use water, we must be sure that we accomplish what we attempt to do. Indiscriminate or impractical utilization will result in problems. We must understand the limitations and capabilities of our water usage and dedicate sufficient attention to its management if we are to use it effectively.

PROPAGATION MEDIA: WHAT A GROWER NEEDS TO KNOW

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There is no one best material or combination of materials for every grower and every propagation need. Thus, it is important to understand some of the overall basics, not just characteristics of specific media.

DESIRABLE MEDIUM CHARACTERISTICS

A list of desirable characteristics of a propagation medium published by Matkin, *et al.* (2) in 1957 differs little from the list of Hartmann and Kester (1) in 1983. Our list which follows has new wording but has nothing new in theory. A grower needs to know if his *medium*:

1. Will hold cuttings upright.
2. Will assure adequate aeration.
3. Will retain adequate moisture so that watering does not have to be too frequent.
4. Is readily available in a consistently uniform grade.
5. Is free of weed seeds, nematodes, and plant pathogens.
6. Is durable; volume change is negligible, structure retains porosity, and chemical makeup is stable to steam or fumigation.
7. Is free of excess salts or toxic chemicals and preferably has low fertility.
8. Is somewhat resistant to loss of nutrients by leaching, especially where used for direct-stick propagation.
9. Is relatively inexpensive.
10. Is relatively light in weight.

MEDIA MATERIALS

Many materials have been tried and tested, accepted and rejected and often tried again in an attempt to find the ideal medium. Listed in the literature (1, 2, 3, 4) and personally observed are: soil; sand that is further identified by terms including fine, coarse, brick, concrete, plaster, bank, pit, silica, and torpedo; peat, peat moss, peat humus; gravel; sphagnum moss; flu ash; fly ash; pumice; perlite; vermiculite; cinders; sawdust (many kinds); wood shavings; rice hulls; compost; manure; leaf mold; pecan hulls; calcined clay; styrofoam; sheet plastic over humid air chamber; water; and rockwool. Many of these materials are used both alone or in combina-

tion. Some materials that are not desirable alone may add desirable characteristics when mixed with other materials.

HOLDING CUTTINGS UPRIGHT

Very light-weight materials such as perlite may not hold large cuttings upright unless mixed with other materials to add weight and allow slight compaction.

ADEQUATE AERATION

The most common problem we have observed in propagation is inadequate aeration, usually resulting from excessive watering by misting or fogging. Soil, fine sand, peat, peat humus, ash products, compost, and leaf mold usually should not be used alone due to poor aeration. However, these same materials may be desirable additives to increase resistance to loss of nutrients by leaching when mixed with coarser, more porous materials; 25% non-capillary pore space should provide adequate aeration.

MOISTURE AND NUTRIENT RETENTION

Both moisture and nutrient retention are more important for direct-stick propagation (sticking cuttings directly into container/beds/fields for growing-on), than for cuttings that are transplanted as soon as they are rooted. The materials mentioned above generally aid nutrient retention as well as moisture retention. Coarse sand and gravel used alone usually would not hold adequate moisture and nutrients.

READILY AVAILABLE, CONSISTENTLY UNIFORM

Few naturally occurring inorganic materials are available in a uniform grade. Soils vary greatly in particle size distribution as do sands. Commercially marketed organic materials such as peat moss, rice hulls, and ground bark usually are readily available in uniform and reliable quality.

Perlite, vericulite, pumice and calcined clay are examples inorganic materials that are readily available and consistently uniform.

FREE OF WEEDS AND PATHOGENS

Many good materials are relatively weed- and pathogen-free for first-time use. Peat moss, perlite, vermiculite, pumice, cinders, and even bark usually are safe to use without steaming or fumigating. However, when re-using any medium, fumigation or some sort of sterilization is a recommended practice.

LOW SALINITY AND FERTILITY

Few would question the need for a materials with low salinity, but some may question the intentional use of materials of known low fertility. We think it is much easier and safer to add desirable nutrients from a known low level than to run soil tests and make adjustments. It is difficult to remove undesirably high levels of salts, plant nutrients included.

RELATIVELY INEXPENSIVE

Few propagation media are prohibitively expensive as a propagation medium, considering the value of the crop to be grown. However, costs should not be ignored when less expensive materials may do just as well. We think the medium should be as deep as possible to provide space for excess water to settle. When a relatively expensive medium is used, the inclination to reduce medium depth is greater. Also, propagation in the same medium as used for growing is recommended, thus making a relatively inexpensive medium highly desirable.

LIGHTWEIGHT

A light-weight, or low density, medium generally is desirable for ease of mixing, handling, shipping, and transplanting, but there may be some undesirable aspects in certain situations. For example, when transplanting potted liners to field soils, plants grown in lightweight media usually establish more slowly. This probably is due to unequal moisture levels across the light-weight, heavy soil interface.

SUMMARY

Our topic was "Propagation Media—What a Grower Needs to Know." We haven't given you many answers, but hopefully we have told you a few things you "need" to know. The medium that works for one grower may not work for another unless both use the same containers and trays, use the same structure, have similar quality water, have similar weather, and follow similar watering, transplanting, and fertilization programs. Media alone will not assure successful propagation. But, if you know the 10 characteristics we have listed, problems should be fewer.

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UTILIZING AIR ROOT PRUNING IN NURSERY SEEDLING PROPAGATION

BEN DAVIS, II

H. J. Judkins and Son Nursery, Inc.
Route 4, Box 180
Smithville, Tennessee 37166

Judkins Nursery decided to diversify its product line by starting two new operations: tree growing in 5-gallon containers, and field production of large-caliper trees. A new propagation facility was needed to supply a broader range of plant species and better quality liners to the new operations.

Why use the air root-pruning system? *First*, it produces a superior root system without the winding common in other types of container-grown seedlings. *Second*, it offers accelerated growth through controlled growing conditions. *Third*, the liners can be moved to the next step in the production cycle without shock or loss of the momentum gained from the accelerated growth. *Fourth*, the transplanting can be done in the late summer or early fall when the nursery work load is at its lowest point. This system was brought to management's attention by the writer, who had observed the work of Dr. Carl Whitcomb and his students in experimenting with growing seedlings in milk cartons. These experiments were reported at Oklahoma State University Nursery Research Field Days over a period of several years.

There were two main objectives of the new system. *First*, to produce a salable 6- to 8-foot tree in a 5-gallon container in two growing seasons from a seed. *Second*, to produce a better quality liner for the field that could be transplanted in late summer or early fall.

FACILITY AND MATERIALS

The site was graded to assure good drainage and covered with approximately 2 in. of ¾-in. aggregate crushed limestone. Three water lines were installed 30 feet apart with risers 32 feet apart in each line. This spacing allowed the placement of five raised

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FACILITY AND MATERIALS

The site was graded to assure good drainage and covered with approximately 2 in. of ¾-in. aggregate crushed limestone. Three water lines were installed 30 feet apart with risers 32 feet apart in each line. This spacing allowed the placement of five raised

benches between each set of risers.

The benches were constructed by laying three rows of landscape timbers on the ground, each row 80 feet long. On top of these were placed five cattle or corral panels, each measuring 52 inches wide by 16 feet long. This created a bench approximately 4-in. off the ground, measuring 52 in. wide by 80 feet long.

Each bench accommodates 153 Lerio plastic flats in 51 rows, three flats wide. The flats have grid bottoms, which allow air root pruning. Each flat holds 25 square, bottomless pots measuring 3⅝ in. by 6 in. deep.[1] Thus, each bench holds 3,825 pots.

The potting mix used was the same as the nursery's container mix and consists of four parts fine ground pine bark and one part concrete sand. To each cubic yard of this mix is added 12 pounds of dolomitic limestone, six pounds of Osomocote 18-6-12, and 1½ pounds of Micromax.

OPERATIONS

Seed stratification was carried out for each species in the normal manner using, by volume, 50 percent sand and 50 percent peat as the stratification medium. The sand and peat were screened so that the particles would be smaller than the seed being stratified. This was to facilitate screening out the seed at the time of seeding.

Flats were prepared for pots by placing a folded sheet of newspaper in the bottom of each flat. Pots were filled individually and tamped to prevent the mix from sifting out the bottom during handling. The newspaper in the flats kept the mix from washing out the bottoms of the pots once they were in place. By the time the newspaper had deteriorated, the mix had settled enough to stay in place. Each person in the pot-filling crew filled and placed on the benches 35 flats per day, or 875 pots. Pot filling was managed so that pots were filled seven to 10 days ahead of seeding.

As each species of seed came due for seeding, the stratification medium was screened out of the seed to facilitate seeding. Small seeds were sown in multiples in each pot according to germination projections. Large seeds (the *Quercus* species) were pre-germinated and seeded one per pot as soon as a radicle was apparent. These seeds were examined every one or two days and only those ready were planted. All seeds were covered with sand to the appropriate depth. Seeding began on March 3, 1986, and was completed on April 25, 1986.

After seeds had germinated, some pots had no seedlings in them. When it was time to thin the multiple seedlings, some of these were transplanted to the pots having none.

Weeds were controlled by hand, and spraying was done on an

[1]McCalif Growers Supplies, Inc., 2215 Ringwood Avenue, San Jose, CA 95131, (408-946-5773).

as-needed basis to control insects and diseases. Fertilizer in the mix was supplemented with both hand fertilization and overhead sprinkler-applied fertilizer. This was begun the first week in June. Ammonium nitrate was hand-applied at the rate of ¾ lb. per 100 ft.^{2}, once each week. Liquid 12-3-3 fertilizer was also applied once each week through the irrigation system at the rate of 2.9 lbs. per 100 ft.^{2}. The fertilizer was discontinued on September 1.

Beginning on September 22 liners that had previously been graded and pruned were shifted up to 5-gal. containers. The container mix previously cited was used except that a 12-6-6 nursery fertilizer was substituted for the Osmocote. The rate was 5 lbs. per yd.^{3} These containers were placed can-to-can and were mulched with straw to carry them through the winter. The remaining liners were planted in the field in 6½-foot rows, four feet apart in the row. Every fourth row was skipped to leave a drive for digging later. These liners were planted in October and November when weather permitted, and will be grown to 2 in. and larger caliper. Plans called for the installation of drip irrigation of these trees when possible.

COSTS

To arrive at a cost per seedling, the durable materials were amortized over their estimated useful life. Container yard space and benches were amortized over five years, and pots and flats were amortized over three years. These indirect costs were 8.1 cents per pot and direct costs for materials and labor were 28.3 cents per pot. The total cost per pot was 36.4 cents. The average percentage of pots producing usable liners was 59.5, making the average cost per usable liner 61.2 cents. This somewhat high figure was caused by the almost total failure of two or three species of the 18 that were attempted. However, most of the *Quercus* species were highly successful, yielding 92 to 96 percent usable seedlings. Table 1 lists the species attempted and the estimated percentage of pots producing usable seedlings.

Table 1. Species attempted and the estimated percentage of pots producing usable seedlings.

Species	Percentage	Species	Percentage
Acer rubrum	0	*Pistacia chinensis*	96
Betula nigra	1	*Quercus acutissima*	88
Cercis canadensis	50	*Quercus alba*	25
Elaeagnus angustifolia	50	*Quercus falcata* var. *falcata*	50
Koelreuteria paniculata	84	*Quercus nigra*	96
Liquidambar styraciflua	96	*Quercus palustris*	96
Liriodendron tulipifera	25	*Quercus phellos*	96
Pinus sabiniana	50	*Quercus rubra*	50
Pinus strobus	10	*Quercus shumardii*	92

PROBLEMS AND POSSIBLE SOLUTIONS

As mentioned, seeds of some species totally failed to germinate. Some failure was attributed to incorrect stratification procedures. In other cases, poor germination was due to covering the seed too deeply. In those cases where corrective action cannot be determined with reasonable certainty, the species will be dropped from the propagation schedule. Some seeds germinated successfully, but the seedlings were frozen shortly afterwards. Therefore, planting should probably begin about two weeks later.

Overcrowding was a problem with species that had heavy foliage, such as *Cercis canadensis, Koelreuteria paniculata,* and *Liriodendron tulipifera.* The large pot size helped but did not give the plants enough space near the end of the growing season. These plant types need to be shifted or transplanted earlier in the summer. Unfortunately, the container area being constructed to hold these was not ready in time.

Some of the *Quercus* seedlings did not make as much top growth as they should have. They appeared to be stunted with no discernible cause. In a conversation with Carl Whitcomb, he explained that when *Quercus* seeds are planted after the radicle is showing, auxins will have already sent a "message" to the radicle as to which direction is down. Therefore, it is highly likely that some *seed are planted upside down, based on this orientation. Dr.* Whitcomb stated that it would be better not to plant until the radicle had actually turned, indicating its orientation, and allowing it to be planted pointing downward.

Another problem was that some species did not air root-prune properly at the bench height used. Evidently there was not enough air circulation to kill the roots as they emerged from the bottoms of the pots. While no roots actually grew into the ground, they did extend 2 or 3 in. from the bottom of the pot. The remedy for this, of course, is to place some blocks under the landscape timbers supporting the benches. This will allow for cross ventilation.

SUMMARY

The operation will be expanded next year and the refinements and corrections mentioned will be made. The system offers advantages over conventional growing methods that make the extra effort worthwhile. *These are as follows:* (1). A better quality liner with accelerated growth characteristics! (2). A reduction in growing time to produce a salable sized tree. (3). A liner that can be shifted up to a larger container or transplanted during late summer or early fall when work loads are lightest in the nursery.

PROPAGATION OF *ACER TRUNCATUM*, A NEW INTRODUCTION TO THE SOUTHERN GREAT PLAINS[1]

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Abstract. *Acer truncatum*, a new introduction to the plains, normally hardy only to USDA zone 6 except in its hybrid form with *A. platanoides*, has performed well throughout Kansas (zones 5 and 6). It has survived considerable heat and drought stress, has had no serious pest problems and has been resistant to leaf scorch. Propagation has been successful from seed stratified for 30 days. Softwood cuttings taken in August rooted better than those taken in late May. Best rooting occurred with basal portions treated with 1,000 to 5,000 ppm IBA although over 50% rooted without the use of hormone.

In contemporary landscapes maples that mature at 25 to 30 feet in height are very useful, especially if they are tolerant of a wide range of planting conditions. Often overlooked species include *Acer truncatum* (7), the shantung maple, also called purpleblow maple because of the often reddish-purplish color in its new foliage. Native to northern China, the species was first introduced to the United States in 1881 but has not been in wide cultivation in the nursery trade.

Plants used in this evaluation were obtained from the USDA Plant Introduction Station, Ames, Iowa under the accession number PI-18578. It was originally introduced to the U.S. by F. N. Meyer following a plant exploration trip to the Weitsan mountains near Peking in 1906. Trees were established at Wichita (zone 6) and Colby, Kansas (zone 5), in 1973 as part of a North Central states regional project. The species did not prove to be hardy in any of the North Central states except Kansas, although it reportedly grows as a small shrub at the Morden Research Station, Manitoba, Canada. A hybrid with *A. platanoides* has been hardy at the Minnesota Landscape Arboretum. Plants survived at at both locations, including the northwest test site at Colby where winter temperatures often reach −20°F (−29°C).

Performance has been excellent at Wichita, under very hot, dry conditions and has been resistant to leaf scorch. No pest problems have been observed except an occasional tar spot on leaves of trees at Colby. Results of both seed and cutting propagation are reported here.

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[1]Contribution No. 87-139-A, Kansas Agricultural Experiment Station, Kansas State University, Department of Horticulture, Manhattan, KS 66506.

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REVIEW OF LITERATURE

Traditionally, seeds of many maples that mature their samaras in the fall need to be stratified 60 to 90 days (13). In recent years many species have also been vegetatively propagated by softwood cuttings, especially *Acer rubrum* cultivars (4,5,10), but also *A. campestre, A. ginnala, A. platanoides,* and others (1,2,3). Seed propagation is often preferred for genetic diversity, but vegetative propagation has advantages where seed is limited and, more importantly, when superior selections are to be clonally propagated. *Acer truncatum* and *Acer truncatum* subsp. *mono* closely resemble *A. cappadocicum,* the coliseum maple, which has proven so well adapted to Oklahoma (12). It, too, has a milky sap like *A. truncatum* and has been propagated by softwood cuttings in June (2).

Fall color of *A. truncatum* is often late and variable, although this has shown to be affected by moisture level. Irrigated trees in California colored significantly better than non-irrigated trees, although fall coloration occurred four to five days later than trees under drought stress (8). Of three original specimens obtained, the parent tree for these investigations has shown superior fall color each year. The tree is planted on a dry, sandy site and receives no appreciable irrigation during summer. The objective of this study was to propagate this tree vegetatively and to evaluate it with other seedlings for superior fall color.

MATERIALS AND METHODS

Two separate experiments were conducted to study both seed and cutting propagation of this species. They are discussed separately below.

Experiment 1: Seed Propagation. Seed from two different, 12-year-old trees were collected in October, 1985, to determine the stratification requirements for best germination. Seed were stored dry at 34°F until February, 1986, then sown in moist peat: sand (50/50 v/v) and stratified at 34°F for 30, 45, or 60 days. Flats of both seed lots were removed at 30, 45, or 60-day intervals and germinated at 65°F. Additional seed flats were also treated with the fungicide benomyl as a drench at the rate of 1 tbsp/gal. of water before placing in the cooler in an attempt to reduce root rot.

Experiment 2: Vegetative Propagation. In a preliminary study softwood cuttings were taken from trunk sprouts off a 10-year-old tree in 1982. Cuttings were sectioned into 6-in. (15 cm) lengths, given a 10-sec. dip in an IBA solution at 0, 1,000, 5,000, and 10,000 ppm. Cuttings were placed in sand under intermittent mist having intervals at 10 sec. mist every 6 min. in an outdoor propagation bed with 55% shade. After rooting, cuttings were potted, overwintered in an unheated polyhouse, and planted in a nursery row the following spring.

During 1986, softwood cuttings were taken at two dates from three-year-old seedlings in a nursery row and treated in a similar manner as above. The first cuttings were taken May 29 and evaluated August 6. The second group of cuttings was stuck August 8 and evaluated September 30. Where possible, basal sprouts were used to obtain juvenile growth but some lower branches were also used to supplement numbers of cuttings needed. Cuttings were sectioned into terminal and basal portions approximately 6-in. (15 cm) in length and given a quick (5-sec.) dip in IBA solution at 0, 1,000, 2,500, and 5,000 ppm. Since we observed injury earlier in 1982 at the 10,000 ppm concentration that treatment was omitted. Three replications of 10 cuttings each were used in May, but due to limited cutting material only two replications were possible in August. Photoperiod was extended to 15 hours on August 27 in a manner similar to that used by Smalley and Dirr (6), and by Waxman (11) to encourage vegetative growth after rooting and better winter survival.

RESULTS

Experiment 1: Seed Propagation. Germination was quite rapid with 96% emerging in seed lot No. 1 after only 30 days stratification, with no increase in emergence after longer stratification periods (Table 1). In fact, upon examination, some radicles were observed emerging after only two weeks of moist-chilling. The reduction of seedling stand after 45 days may have been partially attributed to stem and root rot from being in stratification too long. Mortality of some seedlings was attributed to some cotyledons not being able to break the seed coat if allowed to dry out.

Table 1. Germination and emergence of *Acer truncatum* seed after various stratification periods.[1]

Tree No.	Length of stratification	Percent germination	Percent emergence
1	30	96%	96%
	45	94	86
	60	85	73
2	30	67	46
	45	83	67
	60	61	54

[1]Mean of 3 replications of 20 seed each.

A fungicide drench with benomyl gave only slight improvement in percent germination. After 60 days of stratification, 93% of treated seed germinated compared to 85% of untreated seed (data not shown). It would appear that with the very short stratification requirement, seedlings should be given light and warm temperature after 30 days of cold-moist conditions in order to hasten the development of healthy seedlings. This could also accelerate

growth, which traditionally has been slow the first growing season.

Experiment 2. Vegetative Propagation. In preliminary studies in 1982, 71 and 79% rooting of terminal sections occurred at 1,000 and 5,000 ppm, respectively (Table 2). Decreased rooting occurred at 10,000 ppm due to basal injury to the cuttings.

Table 2. Effect of IBA concentration on the rooting of *Acer truncatum* softwood cuttings.[1]

IBA Conc. (ppm)	Percent rooting
0	43%
1,000	71
5,000	79
10,000	10

[1]Terminal cuttings collected June 8, 1982 from a 10-year-old tree.

During 1986, good results were obtained with terminal and basal portions taken at two different dates although better rooting occurred with cuttings taken in August than May. This agrees with Vertees (9) who reported poor results with cuttings taken in June. Another reason for poor results in mid-summer was due to wind, which affected the mist pattern in the outdoor propagation bed during June and July. Nevertheless, some rooting occurred at all concentrations of IBA. Most rooting occurred on terminal portions treated with 1,000 ppm, and with basal portions dipped in 2,500 ppm IBA (data not shown).

Cuttings taken in early August rooted quite successfully by mid-September. Maximum (75%) rooting of terminal portions occurred at the 1,000 ppm concentration. In contrast, increased rooting occurred on basal portions at concentrations of IBA increased (Table 3). The number of roots per cutting was greatest at 1,000 ppm due to some basal injury to the cuttings at higher concentrations, especially at 5,000 ppm. At the higher levels of IBA, most rooting occurred above the treated area. Although only five roots per cutting developed in the best treatment, roots were vigorous and usually extended several inches into the sand medium (Figure 1).

Table 3. Effect of stem portion and IBA concentration on rooting of *Acer truncatum*.[1]

IBA conc. (ppm)	Stem portion	Percent rooting	No. roots per rooted cutting
0	Terminal	35%	2.5
	Basal	55	4.6
1,000	Terminal	75	5.0
	Basal	60	5.2
2,500	Terminal	50	2.6
	Basal	75	3.9
5,000	Terminal	60	3.8
	Basal	85	4.7

[1]Mean of 2 replications of 10 cuttings.

Although 5,000 ppm IBA increased rooting of basal portions to 85%, higher concentrations were apparently not justified. In a separate group of cuttings, Hormodin No. 2 and No. 3 (3,000 and 8,000 ppm IBA, respectively) were compared. Best results were with Hormodin No. 3, which produced 50% rooting of terminal portions and 60% of basal sections. Half the cuttings were potted in a pine bark:peat:sand medium (2:1:1 v/v) and kept under long days to encourage some vegetative growth before winter. The other half were left in the propagation bed to overwinter before lifting in the spring.

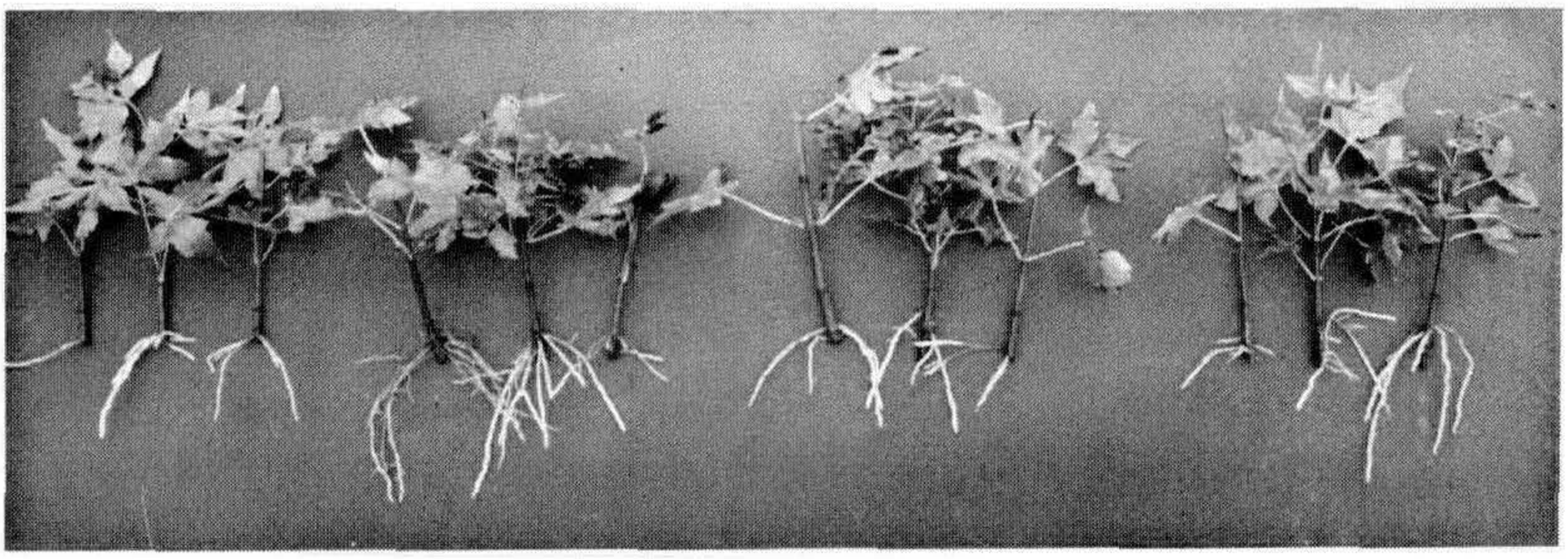

Figure 1. Rooted stem cuttings of *Acer truncatum* taken August 8 and dipped into various IBA solutions. *Left to right:* Control, 1000 ppm, 2,500 ppm, and 5,000 ppm.

DISCUSSION

The shantung or purpleblow maple has shown excellent adaptability to the southern Great Plains and arid sections of the Southwest. Propagation was easily accomplished by both seed and softwood cuttings. A 30-day stratification period is apparently sufficient to break seed dormancy of this Asiatic maple. Extra precautions may be required during seed germination to obtain maximum survival of seedlings compared to other maple species. This may explain to some degree the limited use of this tree in the nursery trade.

Cuttings taken in late summer rooted in seven weeks and produced healthy liners for fall potting or leaving in the propagation bed until spring. Some growth after rooting to restore carbohydrate reserves is important for good winter survival of cuttings taken late in the season.

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PROPAGATION MEDIA FOR FLATS AND FOR DIRECT STICKING: WHAT WORKS?

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Lone Star Growers is a 175 acre wholesale nursery, located in San Antonio, Texas. We are a very diverse operation, with a Color Department growing seasonal flowering crops, a Native Plant Department that is aggressively expanding its production of Texas and Mexican plants, and a container production of woody ornamentals. We sell plants ranging in size from 2¼-in. rose pots to 24-in. boxed trees.

Currently we are growing 350 cultivars of woody ornamental plants. This number does not include the seasonal color or the native plants, which is a significant number more. Of these 350 cultivars, it seems that each one is just a little different in its needs to root and grow.

The Propagation Department at Lone Star Growers consists of 108,000 ft.^{2} of intermittent mist space. We have Biotherm bottom heat on 35,000 ft.^{2} of mist, enabling year-round cutting production.

Our average annual production in propagation is 3.7 million 2¼-in. rose pots and 300,000 4-in. pots. The majority of this is for our own canning purposes. We also grow for liner and 4-in. sales.

We use several methods to root cuttings under intermittent mist:

1. Sticking the cuttings into a standard 16¾-in. × 18-in. × 2½-in. flat with an average of 250 cuttings per flat.
2. Sticking cuttings directly into 2¼-in. rose pots (direct stick)—56 per flat.
3. Direct sticking cuttings into 4-in. pots, 25 per flat.
4. Direct sticking cuttings into 1-gal. containers.

The primary factor determining which method we use is cost. The cost per ft.^{2} to root cuttings in gallon containers in the mist bed is the most expensive. Only 4 gallons per ft.^{2} fit into a bed, compared to 26–2¼ in. rose pots or 120 cuttings in flats. Excluding materials, cost per ft.^{2} of mist space dictates that only a few crops be rooted in gallons. These crops must also produce 95% rooting and be in and out of the mist in 4 to 6 weeks.

Rooting cuttings directly in a 2¼-in. rose pot is my favorite way of propagating ornamentals. The initial cost per sq. ft. of mist space and materials is higher than rooting in flats, and for this reason we must get 80% rooting or better to justify direct sticking. However, when the cutting roots, it is off and growing. No transplant shock or

losses from potting occur for this method so the end result is a better plant and quicker turnover at a savings over potting.

Cuttings rooted in a flat with propagation mix is the least expensive rooting method. We stick 256 cuttings in a 16¾-in. × 18-in. × 2½-in. plastic flat. This method is used primarily to keep the cost down on difficult-to-root crops and when mist space is limited, such as during the winter when we cannot use our outside mist.

The Propagation Department is currently using the following soil mixes:

1. Cutting flat mix: 1 part pulverized pine bark, 1 part coarse perlite, 1 lb./yd.^{3} Micromax, and 4 lbs./yd.^{3} Osmocote 18-6-12

The cutting flat medium is economical and works well for the majority of our cuttings stuck into flats. Most of the crops rooted in flats are the more difficult-to-root species, and we want a very porous medium for these cuttings. We do not use this as our standard mix because it is more expensive and the root ball falls apart easier than in our standard potting mix. It is important to have a medium that holds together when the plant is shifted to a larger container or is planted in the ground. This mix has a total porosity of 60 percent, made up of 25 percent air space, and 36 percent water-holding capacity.

2. Nandina cutting mix: 3 parts pulverized pine bark, 2½ parts peat moss, 2½ parts coarse perlite, 1 lb./yd.^{3} Micromax, and 4 lbs./yd.^{3} Osmocote 18-6-12

This medium is used mainly for nandinas and a few other crops that do better in this mix than in our flat mix. We developed this through trial and error to increase rooting percentage on nandinas. This mix has a porosity of 55 percent, air space 25 percent, water holding capacity 30 percent.

3. Standard potting mix: 7 parts pulverized pine bark, 7 parts large red pine bark, 2 parts coarse builders sand, 1 lb./yd.^{3} Micromax, and 9 lbs./yd.^{3} Osmocote 18-6-12

This mix is used for direct-stick crops and is our potting mix for liners. With the high bark content the potting mix has a pH of 6.5, good porosity and air space. Most of our crops grow well in this mix, which is our main growing mix. Porosity is 53 percent, air space 20 percent, water holding capacity 53 percent.

4. 50/50 bark mix: 1 part pulverized pine bark, 1 part large red pine bark, 1 lb./yd.^{3} Micromax, and 9 lbs./yd.^{3} Osmocote 18-6-12

The 50/50 mix is for direct-stick crops that are more sensitive to decay under the mist. It is a good porous mix; however, after six to eight months it tends to compact, losing some of its air space. The sand in our standard potting mix prevents this compaction. Porosity

is 53 percent, air space 27 percent, water-holding capacity 26 percent.

The availability and low cost of pine bark in Texas makes it a popular component of soil mixes for larger container plants. A lot of bark is used in our propagation soil mixes. The pulverized pine bark has a small particle size with good consistency, and we use it as a substitute for expensive peat moss. We have also found pine bark reduces disease problems from soil-borne pathogens (1). Without incorporating any fungicide our bark mix shows less basal decay of cuttings than other media we have used.

When cuttings of many species are rooted under mist, nutrients can be leached from the cutting. In addition, some media have very low nutritional levels. Various degrees of yellowing or chlorosis occurs, which stresses the cutting, delaying rooting or causing the cutting to die. If the plant does root, it is slow to grow, probably due to nutrition problems. We continually try different fertility treatments during propagation to produce healthy rooted cuttings. A recent trial by our Research and Development Department shows the benefits of fertilizer and microelement additives to various propagation media.

Three propagation mixes were compared, with combinations of Osmocote 18-6-12 and Micromax microelements as additives:

a. Propagation Mix—(perlite: composted bark, 3:1 v/v)
b. Propagation Mix—(plus Osmocote 18-6-12, 9 lbs./cu.^{3})
c. Propagation Mix—(plus Osmocote plus Micromax, 1 lb./cu.^{3})
d. Native Mix—(screened peat: vermiculite: perlite, 3:3:4, v/v)
e. Native Mix—(plus Osmocote as above)
f. Native Mix—(plus Osmocote plus Micromax as above)
g. Fine bark: perlite, 1:1, v/v—(plus Osmocote plus Micromax as above.)

Cuttings of *Lagerstroemia indica* and *Hibiscus rosa-sinensis* were planted in each mix for comparison. Cuttings were placed in the mist and treated as they would be normally for the species. When the cuttings were rooted sufficiently for the individual species, they were evaluated for leaf color and plant heights (Figures 1 and 2).

As evident from the height charts the addition of Osmocote increased growth significantly, and the addition of microelements plus Osmocote produced another growth increase.

When leaf color is compared, it is evident again that the combination of Osmocote and Micromax worked well for us (Table 1). The media with microelements incorporated produced darker green color in cuttings. Cuttings were much healthier and continue to be higher quality plants.

Micronutrients, such as Micromax or other comparable

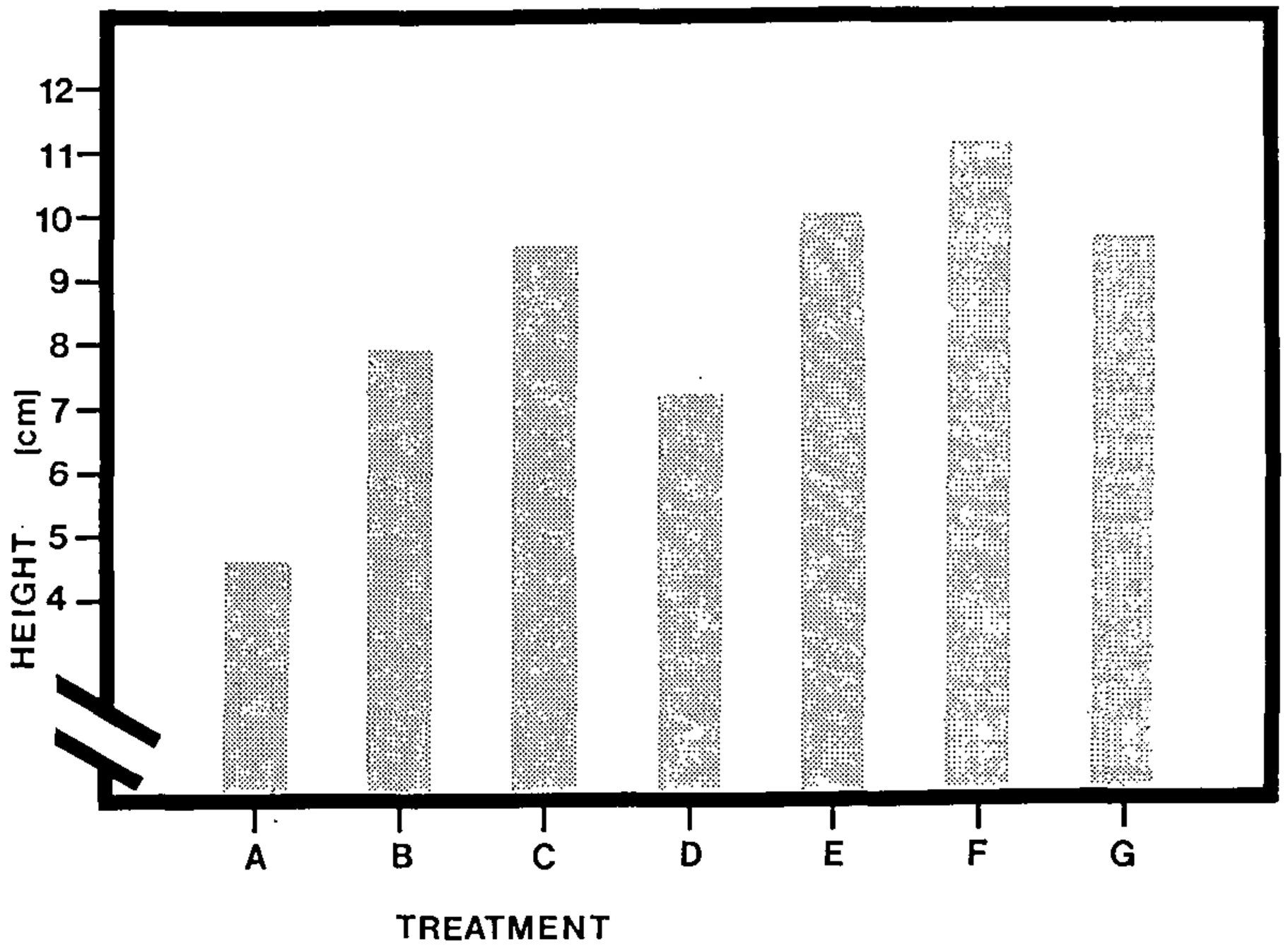

Figure 1. Heights of *Hibiscus* liners using various combinations of media and fertilizers (See text).

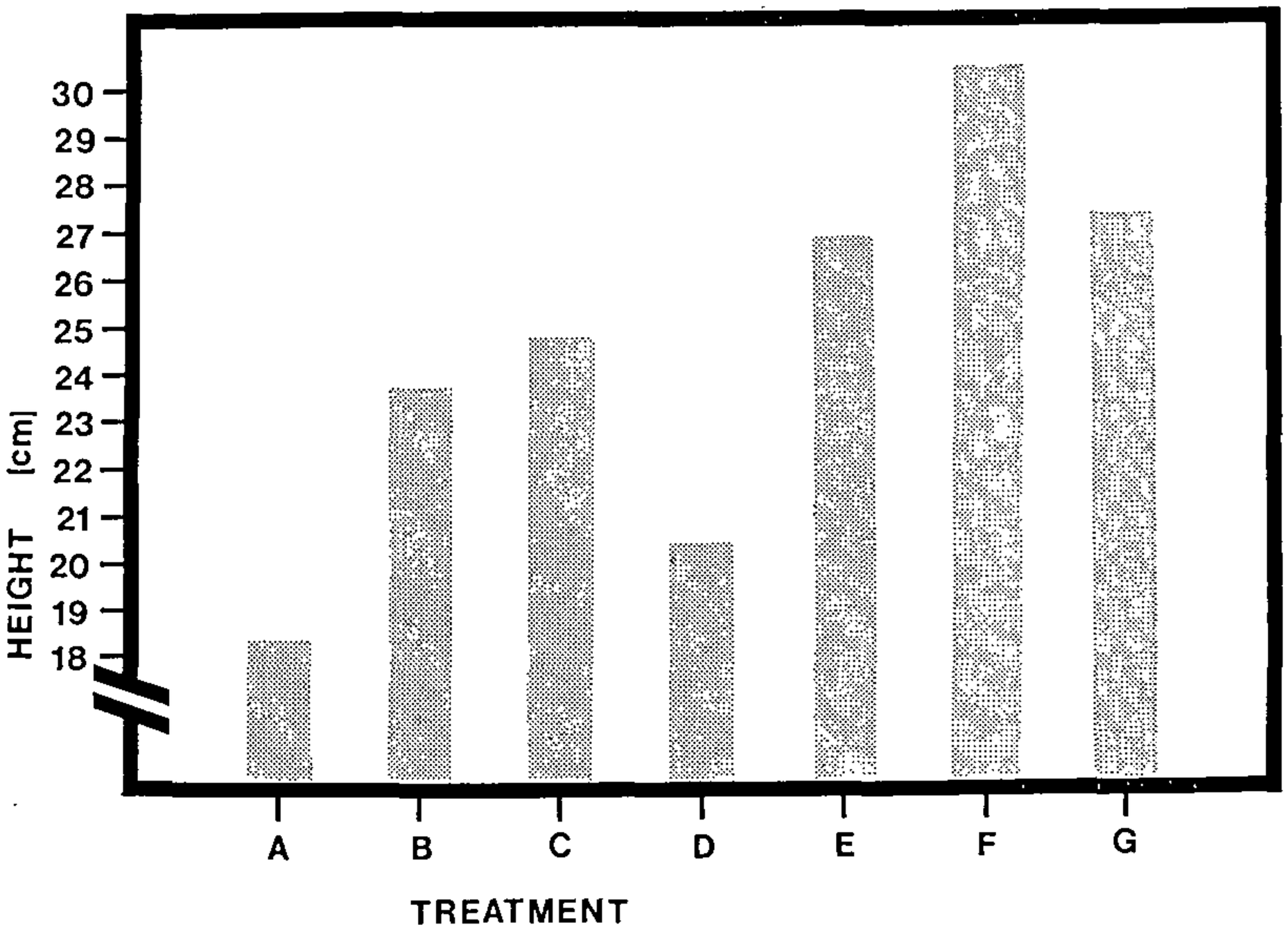

Figure 2. Heights of *Lagerstroemia* liners using various combinations of media and fertilizers. (See text).

Table 1. Quality rating[1] of foliage of *Lagerstroemia* and *Hibiscus rosa-sinensis* plants propagated in seven different propagation mixes.

Treatment (rooting mix) See text	Quality rating	
	Lagerstroemia	*Hibiscus rosa-sinensis*
A	2	2
B	2	2
C	3	4
D	2	3
E	4	4
F	5	5
G	4	5

[1]Quality rating: 1 = worst; 5 = best

materials, incorporated into the mix consistently add vigor and darker green color to the plants grown in the mix. Studies have shown that a plant rooted with microelements in the medium will be more vigorous and desirable throughout the life of the plant. Also, cuttings taken from these same plants will root and grow better than those taken from stock not grown with microelements (2). Lone Star Growers now incorporates microelements into all of its propagation media.

An observation I have made from recent trials and experience is that vermiculite, as part of a growing medium, utilizes nutrients efficiently. Vermiculite has a high cation exchange capacity and could be an important ingredient to any soil in limited amounts (3). We will be doing further trials to find the optimum amount for our mixes and the economics of using vermiculite and other components.

Lone Star Growers is a progressive company. Even though we are growing good quality plants now, we feel that there are better ways to do just about anything. There is no better example of this concept than the propagation area. This is where it all starts. If you want to improve your plant quality, reduce your growing time, and therefore reduce cost, look at your propagation area.

The improvements you make there will be magnified throughout your nursery.

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GRAFTING AND CUTTING PROPAGATION OF PECANS

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Pecan orchards are often established by planting either grafted or seedling trees. Orchard establishment using grafted trees may reduce the time required for fruit production, and no grafting knowledge is necessary. However, grafted trees are more expensive, and cold damage to grafted trees may cause loss of the scion with resprouting from the rootstock. Scion death requires regrafting, which would then delay production. Seedling trees are inexpensive compared to grafted trees; but because additional labor and expertise are necessary for grafting, growers usually prefer to purchase grafted trees. However, a major problem with grafted pecan trees is lack of cold hardiness.

Cold Damage. Cold damage to young pecan trees most often occurs on the trunk near the soil line in the fall. Moderately damaged trees develop vertical splits in the bark, with loss of phloem and cambium in the damaged area. Severely damaged trees may be completely girdled, resulting in the loss of the top and resprouting from the roots. Normally, this type of cold damage does not occur after the trees are 4 to 6 years old.

Pecan rootstocks are produced from open-pollinated seed and, therefore, are very diverse in cold damage susceptibility, tree vigor, and other characteristics. However, seed from certain open-pollinated female parents have shown greater cold hardiness than other selections. Hinrichs (1) reported that 1-year-old trees of 'Stuart' grafted to either 'Giles', 'Indiana', or 'Major' seedling rootstocks were not damaged when exposed to low temperatures in the fall (Table 1). Damage to 'Stuart' trees on other rootstocks ranged from 33 to 83% of the trees damaged. Cold injury on many of these trees was severe enough to kill the tops, with the rootstock resprouting. Trees grafted on 'Giles' seedling rootstock were larger after 5 years than trees on 'Indiana' or 'Major' seedling rootstocks. The largest trees were those on 'Mahan' seedling rootstocks, but 33% of the trees were damaged by fall freezes.

Madden (2) has also reported that the rootstock affects the cold hardiness of pecan trees. He evaluated 'Wichita' and 'Choctaw' trees grafted on 'Apache' or 'Riverside' seedling rootstock. Both cultivars were more cold-hardy on the 'Apache' seedling rootstock than 'Riverside' seedling rootstock (Table 2).

The graft height on the rootstock also has a significant influence on the cold hardiness of the tree. Most fall cold injury to young trees occurs at or near the soil line. By grafting the scion

Table 1. Effect of rootstock on cold damage and growth of 'Stuart' pecan trees in 1960.[1]

Source of seedling rootstocks	Trees damaged Fall, 1961 (%)	Tree height Jan., 1965 (ft.)
'Giles'	0	10.1
'Indiana'	0	9.5
'Major'	0	9.2
'Success'	33	9.6
'Patrick'	33	8.2
'Mahan'	33	12.8
'Green River'	33	8.0
'Stuart'	50	10.4
'Burkett'	50	10.1
'Western'	67	9.2
'Dodd'	67	11.8
'Niblack'	67	9.8
'Love'	67	10.9
'Dooley'	83	7.6

[1]Hinrichs, H. A. 1985. *Proc. Northern Nut Growers' Assoc.* 56:44–51.

Table 2. Effect of rootstock on cold damage of 4-year-old grafted 'Choctaw' and 'Wichita'[1] pecan trees.

Scion cultivar	Source of seedling rootstock	No. trees observed	Trees damaged Fall, 1976 (%)
'Wichita'	'Apache'	83	12.1
'Wichita'	'Riverside'	81	37.0
'Choctaw'	'Apache'	60	8.3
'Choctaw'	'Riverside'	100	39.0

[1]Madden, G. 1978. *Pecan Quarterly.* 12:17.

Table 3. Effect of trunk type on cold damage of 1-year-old 'Gloria Grande' and 'Sumner' pecan trees.[1]

Trunk type[2]	Scion cultivar	No. trees examined	Trees damaged (%)
Juvenile	'Gloria Grande'	125	0.8
Adult	'Gloria Grande'	106	47.2
Juvenile	'Sumner'	700	0.4
Adult	'Sumner'	211	80.6

[1]Sparks, D. and J. A. Payne. 1977. *HortScience.* 12:497–498.

[2]Trees with juvenile trunks grafted into root 12 to 18 in. above soil line. Adult trunk grafted 3 to 4 inches below soil line.

higher on the rootstock, the hardy juvenile rootstock is in the area most frequently damaged. Sparks and Payne (4) reduced cold injury by over 45% by grafting the scion 12 to 18 in. above the soil line (Table 3). Pecan producers that have had frequent cold damage on nursery grafted trees (those grafted at the soil line), are establishing

seedling trees in their orchard, then grafting them 2 to 3 ft above the soil line to avoid cold damage.

Scionwood. Healthy scion wood is essential to successful propagation of pecans. Whip-or-tongue, 4-flap, and inlay bark grafts require scionwood that is collected while dormant. Scionwood is usually collected in February, then stored moist at 34°F in polyethylene bags. One problem frequently encountered is damage to trees from exposure to midwinter cold before the scions are collected. This damage may not affect tree growth or production, but graft survival can be reduced. Therefore, we evaluated scions from several collection dates to determine if scions could be collected before cold damage occurred. This would require scions to be stored up to 3 months longer.

Scionwood was collected from 'Mount' and 'Squirrel' cultivars monthly from November 15, 1983, through March 15, 1984, and stored in polyethylene bags with a moist paper towel at 34°F until evaluated. Scion viability was evaluated by grafting 15 trees of each cultivar using the 4-flap graft, then recording scion survival.

Scion survival of 'Squirrel' was not significantly different among the December through March collection dates (Figure 1). No 'Squirrel' grafts survived when scions were collected in November. Fewer grafts of 'Mount' lived when collected in November than February, but there were no significant differences among the other collection dates.

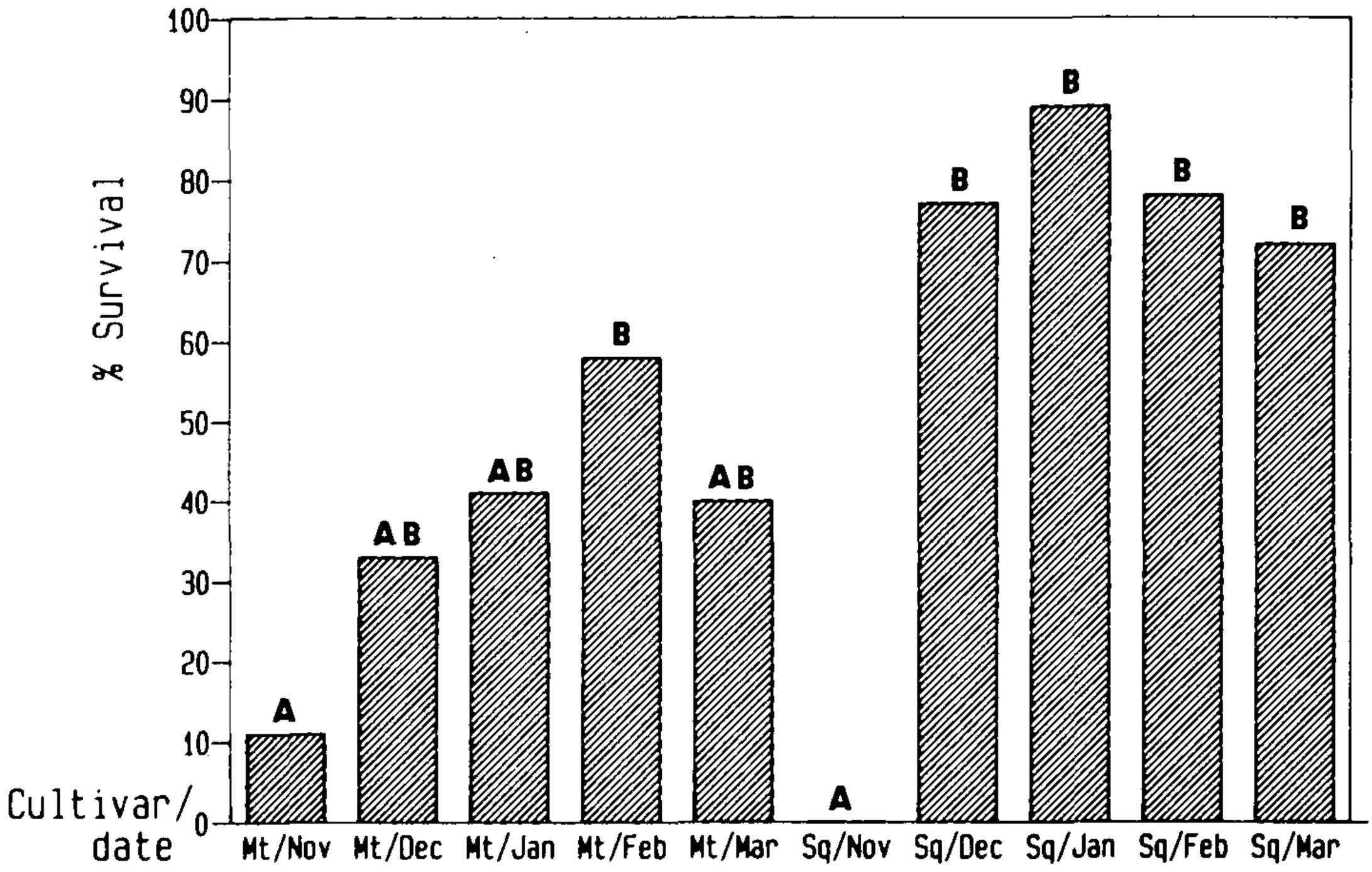

Figure 1. The influence of scion collection date on scion survival when grafted using the 4-flap graft. Mean separation within cultivars using Duncan's multiple range test, 5% level.

The 1983–84 winter was mild, and no scionwood had cold damage from any collection date. However, these results suggest that scion collection in mid-December may be possible to avoid cold damage. Defoliation from frost had occurred November 12 and wood was collected November 15. November scion collection was not successful, indicating that the trees were not sufficiently dormant to allow long term wood storage.

Pecan Rooting. Performance of pecan trees could be improved by selecting rootstocks with desirable traits. However, the inability to propagate pecans asexually prevents the production of uniform rootstocks with desirable characteristics. Therefore, a study was conducted to evaluate the effects of collection date, indole-3-butyric acid (IBA) concentration, and wood type on rooting of pecan cuttings (3).

Juvenile cuttings, from sprouts of 20-year-old seedling trees cut 2 in. above the soil line, as well as adult cuttings taken from vegetative growth in the upper portion of 15-year-old 'Western' trees, were used in factorial combination with four concentrations of IBA. Cuttings were taken on the 15th of February, April, June, August, October, and December to evaluate seasonal changes in rootability. Cuttings 8 inches long were taken from lateral shoots of 1-year-old wood in February and April and from current season's growth in June, August, October, and December. The basal ends of the cuttings were dipped for 3 minutes in IBA solutions of 0, 0.5%, 1%, or 2% and placed under intermittent mist at 78°F. The propagation medium was equal parts of sphagnum peat moss and perlite in 950 ml containers. Cuttings were evaluated for rooting after 90 days. A randomized complete block design with seven replications and three subsamples was used.

Juvenile cuttings rooted better than adult cuttings at most IBA concentrations when cuttings were taken during February, June, or August (Table 4). The rooting percentage of juvenile cuttings was highest during February. Rooting percentage of juvenile and adult cuttings was greatest using 0.5% or 1% IBA.

Lack of rooting during April, October, and December was associated with the absence of foliage on the cutting. Cuttings made during February were dormant, but buds began growth within 2 weeks when placed in the greenhouse. April cuttings had young shoots, but the shoots rapidly abscised. June and August cuttings retained a portion of their foliage, possibly because they were more mature. Senescence had begun in October, and cuttings defoliated soon after being placed under mist. December cuttings did not initiate new growth. Thus, cuttings from February, June and August had foliage, and these were the only treatments in which significant rooting occurred.

Results indicate that both juvenile and adult pecan cuttings can be rooted during certain times of the year. However, the rooting per-

centages may not be commercially acceptable. Furthermore, cuttings were difficult to establish, once rooted.

Table 4. The interaction of cutting source and IBA concentration on rooting of pecan cuttings.

Cutting date	IBA concn.	Rooting Cutting source Juvenile	Adult
February 15	0 %	38%	0%
	0.5	71	5
	1.0	52	5
	2.0	29	0
April 15	0	0	0
	0.5	5	0
	1.0	0	0
	2.0	0	10
August 15	0	0	0
	0.5	10	33
	1.0	29	19
	2.0	10	10
October 15	0	0	0
	0.5	0	0
	1.0	0	0
	2.0	0	0
December 15	0	0	0
	0.5	0	0
	1.0	0	0
	2.0	5	0

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SOFTWOOD CUTTING PROPAGATION OF OAKS, MAGNOLIAS, CRABAPPLES, AND DOGWOODS

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At Simpson Nurseries we propagate trees in many ways including seeds, hardwood cuttings, budding, and grafting. However, the propagation method that we are steadily expanding is that of softwood cuttings. Today I wish to discuss softwood cutting propagation of oaks, magnolias, crabapples, and dogwoods. We have chosen to use the softwood cutting method because seeds are too variable, hardwood cuttings are too limiting, and budding and grafting are too expensive and time-consuming. We have found that softwood cutting propagation is not the answer for all trees. However, we do consider it an excellent method for many shade and flowering trees that have superior shape and fall color, characteristics that we want to maintain.

GENERAL PROCEDURES AND PRACTICES

It is important first to emphasize a few procedures and practices common to the softwood cutting propagation of the four genera of plants we are discussing. The cutting material is gathered in the early morning, between 7:00 and 10:00 a.m. and is immediately placed in wet burlap. It is then transported to the propagation area where it is placed on pallets under a specifically designated mist system.

When we are ready to prepare the cuttings for sticking, the remove the cutting material from the mist system and dip it into a solution of Benlate and Diazinon 4E (eight oz. Benlate plus one pint Diazinon 4E per 100 gal. water). The cutting material is then placed on a table where it is cut into specific cutting lengths, and sometimes wounded, depending upon the plant being prepared.

The cuttings are then dipped into a rooting hormone, using the concentration suitable for the particular plant. We have experimented with mixtures of naphthaleneacetic acid (potassium salt K-NAA) and indolebutyric acid (potassium salt K-IBA). However, we primarily use the K-IBA.

The final step is the same for all four plants; the oaks, magnolias, crabapples, and dogwoods. The cuttings are taken to the nursery's main mist system and rooting area. We use the Parasol nozzle by Spraying Systems and maintain the pressure of the nozzles at 80 to 100 psi.

The cuttings are then stuck ½ to ¾ in. deep into a propagation mix consisting of 35% peat, 40% perlite, and 25% sand (6B gravel)

with five pounds Osmocote (18-6-12) and one pound Micromax per yd.[3] We generally use Lerio 2¼-in. rose pots for rooting. However, we are currently testing some trays by "Tray Masters of Florida" because of their sloped sides and large openings in the bottom.

SPECIFIC PROCEDURES AND PRACTICES

After describing several general procedures used in softwood propagation, it is particularly important to discuss practices that are unique to each of these four plant genera.

Dogwood (*Cornus florida*). At Simpson Nurseries, we have taken dogwood cuttings throughout the summer months. However, our best results occur when the cuttings are taken in May or in late August. The cuttings are 3 to 4 in. long and are taken from hardened current season's growth. Early cuttings are quick-dipped in 1% K-IBA. Late cuttings are dipped in 1% K-IBA for 10 sec. It is preferable to have a node at the base of the cuttings, but it is not absolutely necessary. Callus appears in three to four weeks, with roots forming in six to eight weeks.

Crabapple (*Malus* 'Hopa', *M.* 'Almey,' *M.* × *eleyi, M. floribunda*). Crabapple cuttings are usually taken in July. We take 2 to 3 ft. shoots from the current year's growth, then cut them into 4-in. lengths. All the leaves are removed from 1-in. of the cutting, starting at the base. Two to three leaves are left at the top of the cutting. The tip is usually too soft to use. We use 0.5% K-IBA as a quick-dip. Callus appears in 2 to 3 weeks with roots forming in 4 to 6 weeks.

Magnolia (*Magnolia grandiflora*) Simpson Nurseries take *Magnolia grandiflora* cuttings from the current year's wood that has hardened off. The time period can range from June to August. The cuttings are taken from southern magnolia trees growing in the container area of the nursery. We select the trees with superior shape, growth, leaf size, and color. The final cuttings are approximately 4-in. long and have one or two whole leaves remaining on them. The bases of the cuttings are cut at a slant or wounded slightly. They are then dipped in 1% K-IBA. Callus appears in 3 to 4 weeks with roots appearing after 6 to 8 weeks.

Oaks (*Quercus virginiana, Q. shumardii, Q. laurifolia*) We have historically grown these three oak species from seed. However, because of variable growth and, in the case of the *Q. shumardii,* variable fall color, we have begun experimenting with the softwood method of propagation.

Cuttings from live oak and laurel oak are normally taken in July from the current year's hardened growth. The cuttings are 2 to 3 in. long and are usually tip cuttings. The thicker stems generally represent better cuttings. Since the leaves and stems are removed from the bottom inch, there is usually a wound, which can take up the K-

IBA. The bases are quick-dipped in 1.2% K-IBA. Callus appears in 4 to 5 weeks with rooting taking place in 7 to 9 weeks.

Cuttings from *Quercus shumardii* are taken in late July from the current year's growth and are 3 to 4 in. long. The wood is not as brittle nor as hard as the wood on the other oak species. We quick-dip the cuttings in 1% K-IBA. Callus appears in 4 to 5 weeks with rooting taking place in 7 to 9 weeks.

CONCLUSION

At Simpson Nurseries we have found softwood cutting propagation to be the preferable method for propagation of certain species of oak, magnolia, crabapple and dogwood. Because of the tremendous success we have experienced, we intend to expand our experimentation and utilization of the process. In our opinion, the potential and merit of softwood cutting propagation have been well documented and demonstrated.

TISSUE CULTURE OF OAKS AND REDBUDS

LISA BENNETT

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Abstract. A micropropagation method for *Quercus shumardii* is described. Stem sections were utilized as explants and shoot multiplication was promoted with WPM amended with BA. BA and 2iP were tested in a range of 0.0 to 5.0 mg/liter with 2.0 mg/liter BA supporting optimal shoot growth. After 6 weeks shoots could be divided and subcultured on a combination of BA, IBA, and GA_3. Shoots were simultaneously rooted and acclimatized after a 15-minute dip in 500 ppm IBA. The methods presented required only minor refinements for the micropropagation of three other *Quercus* species and of *Cercis canadensis*.

REVIEW OF LITERATURE

The list of tissue-cultured woody perennials available to nurseries is increasing. Among these availabilities are: *Amelanchier*, apple, azalea, birch, blueberry, blackberry, dogwood, kiwifruit, *Magnolia*, *Nandina*, poplar, raspberry, *Raphiolepis*, *Rhododendron*, rose, and *Syringa*.

One problem with this list is that for many of the cultivars plants are only available one to two months of the year, and orders must be booked a year ahead. A second problem is that there are no oaks on the list. Oaks are a very highly valued tree, both as timber and as landscape plants.

Oaks are usually sexually propagated since clonal propagation has been limited (2,3,8). Seed propagation of oaks is plagued

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Oaks are usually sexually propagated since clonal propagation has been limited (2,3,8). Seed propagation of oaks is plagued

with problems. Weevils often attack acorns and the seed must be heat-treated to destroy them. Seeds lose viability if allowed to dry out, and seed crops vary widely from year to year (2). The biggest problem with seed propagation of oaks is that they are so highly heterozygous that uniformity is next to impossible.

For this reason Dr. Fred Davies, Professor at Texas A&M University, and I chose oaks as a genus that could benefit from research and development of micropropagation techniques. If an efficient protocol for clonal reproduction could be developed, the problems associated with seed propagation could be avoided.

We were not the first to attempt oak tissue culture. Oak micropropagation has been reported by Seckinger, *et al.* (7) in 1979, Lineberger (4) in 1980, Pardos (6) in 1981, and Vietez, *et al.* (9) in 1985. None of these researchers established plants out of culture conditions.

Vietez (9) achieved the most success of these researchers. Stem sections and embryonic axes of *Quercus robur* were established on Gresshoff-Doy medium with 0.1 to 1.0 mg/liter BA. Less than 75% of the cultures formed shoots, and senescence was a problem in subculturing. Although 20 to 83% rooting was obtained, no mention of acclimatization success was made.

MATERIALS AND METHODS

Sterilization. Single-node stem sections of *Quercus shumardii* served as explants. Sterilization consisted of a four-step procedure of 1% Liquinox for 20 min., 70% ethanol for 2 min., 10% Clorox for 15 to 20 min., and 70% ethanol for 1 to 2 min. This was followed by three rinses in sterile distilled water.

Multiplication. Explants were placed in test tubes with 3 ml of WPM (5), 2% sucrose, and either benzylamino purine (BA) or isopentyl-adenine (2iP) at 0.0, 0.5, 1.0, 2.0, 3.0, or 5.0 mg/liter. Previous studies found WPM superior to MS medium and liquid superior to agar-based medium (1). The pH was adjusted to 5.3 prior to autoclaving and cultures were maintained under Sylvania Gro-Lux fluorescent lights with a 16-hour photoperiod at 26°C.

After 6 weeks, shoots were divided into single-node pieces and subcultured on agar-based WPM amended with BA (2.0 mg/liter), indole-3-butyric acid (IBA) (0.5 mg/liter), and gibberellic acid (GA_3) (1.0 mg/liter).

Rooting. Shoots 10 mm or greater in length were used for rooting. A variety of rooting experiments, both *in vitro* and *in vivo*, were attempted to maximize rooting. Some of the experiments included:

A) 1 to 14 days on 1 to 5 mg/liter IBA followed by transfer to WPM without growth regulators on either agar or filter paper bridges;

B) exposure to IBA, naphthaleneacetic acid (NAA), or combinations of both (0.1 to 1.0 mg/liter) for 6 weeks;

C) quick dips in 500 ppm IBA followed by transfer to agar, sterile vermiculite with WPM, or non-sterile Jiffy-7 pellets; and

D) quick dips in 500 ppm IBA for 0 to 30 min. followed by insertion into Jiffy-7 pellets. Humidity was maintained by clear plastic covers.

After rooting, plants were acclimatized by gradually removing the clear plastic and decreasing the relative humidity. Plants were then potted into a peat:perlite mix with 1.2 kg/m^3 Osmocote (18-6-12) and placed in the greenhouse under mist. After 3 weeks plants were removed from the mist and placed on the greenhouse bench with no special care other than routine watering and pest control.

RESULTS

Sterilization. Depending on the time of year, contamination ranged from 0 to 50%. The lowest contamination occurred in late winter and early spring when the relative humidity was lowest. Single-node stem sections were a better explant source than apical shoot tips because the apical tips produced a whorl of buds that tended to trap fungi.

Multiplication. BA proved to be a more effective cytokinin than 2iP. Increasing BA concentration increased the number of shoots produced, and as many as 10 shoots were produced at 5 ppm BA (Table 1). These shoots, however, showed signs of cytokinin toxicity such as swelling, stunting, and leaf abnormalities. BA at 2.0 ppm proved to be the optimal concentration for shoot multiplication. This concentration allowed for 7 shoots to be produced, of which 2 were large enough for rooting while the others could be subcultured. The rapid transfer technique originally used is not necessary with oaks. Plants need only be transferred at day 7 and again in

Table 1. Effect of growth regulator on shoot growth of shumard oak.[z]

Growth regulator	Concentration (mg/liter)	No. shoots (10 mm)	Total shoot number	Total leaf number
BA	0.1	1.10	1.58	2.19
	0.5	1.06	1.82	2.86
	1.0	1.17	3.65	5.12
	2.0	1.70	7.20	6.48
	3.0	1.32	9.90	6.72
	5.0	0.85	10.48	7.68
2iP	0.0	1.05	1.75	2.40
	0.5	0.92	1.20	1.98
	1.0	0.92	1.07	2.00
	2.0	0.92	1.18	2.15
	3.0	0.92	1.15	2.25
	5.0	0.70	1.10	2.38

[z]Means represent 80 and 40 explants for each BA and 2iP concentration respectively.

2 to 3 weeks. Small shoots and single-node sections could be subcultured when supplied with BA, IBA, and GA_3. Shoots could be subcultured only for 3 passages. After the third subculture a decline in shoot growth occurred. If the shoots were transferred to the basal medium without growth regulators and placed in a low light situation, approximately half would resume growth and could be subcultured again.

Rooting. Shoots could be rooted *in vitro*, but rooting was not consistent (Figure 1). The treatment that produced optimal rooting one time often produced little rooting when repeated.

Because of inconsistent rooting *in vitro* and the high cost of a single rooting stage, shoots are best treated as mini-cuttings (Figure 2). A 15-minute dip in 500 ppm IBA was optimal and resulted in 73% rooting (Table 2). After the relative humidity was gradually lowered, 86% of the rooted plantlets survived the transition to the greenhouse. Although not quite as vigorous as seedlings in the early stages, there was little difference at 5 months, and most are still actively growing after 2 years.

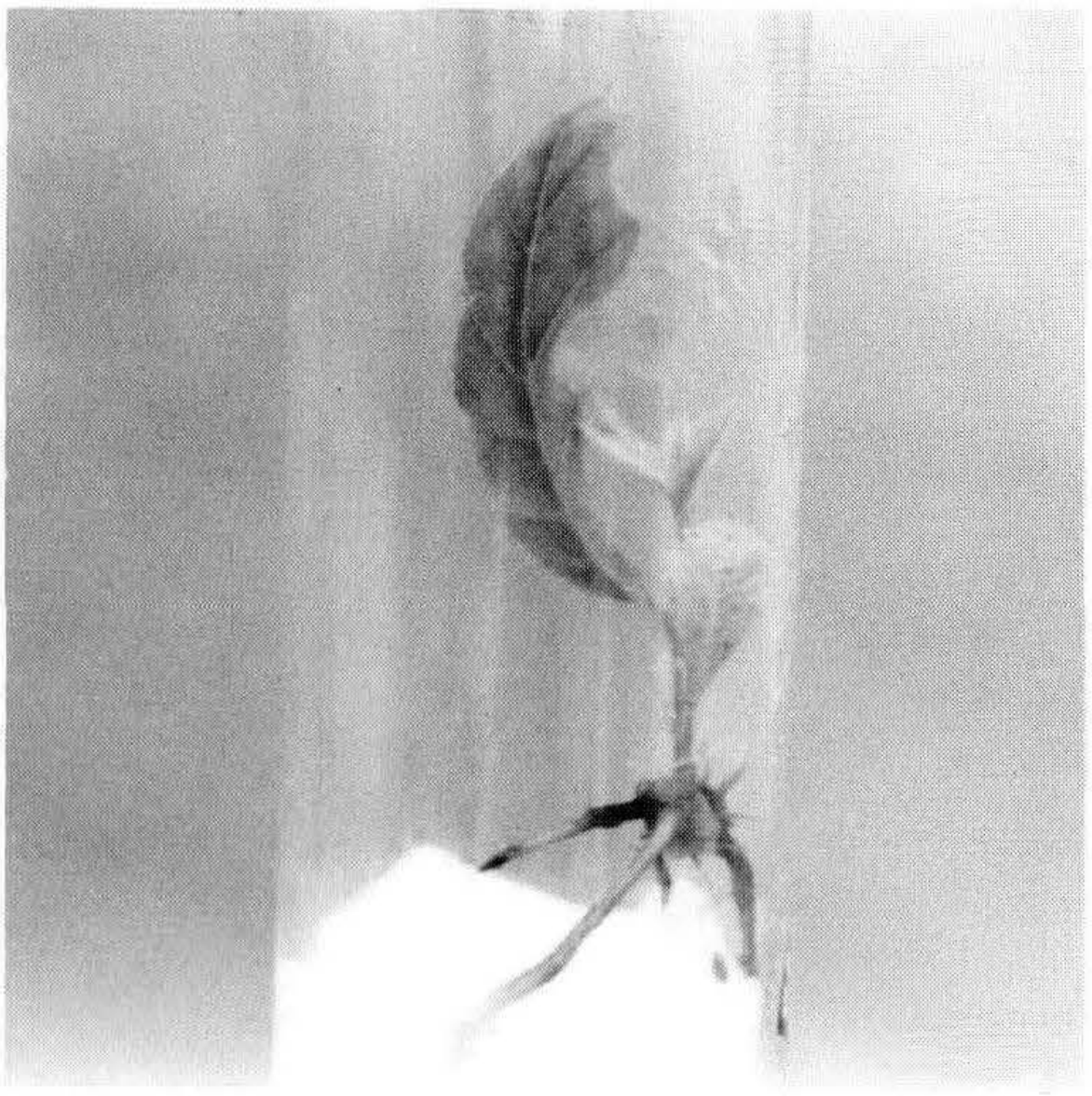

Figure 1. Shumard oak rooted *in vitro*.

Table 2. Effect of time in 500 ppm IBA on percent rooting of shumard oak.[z]

Time (min.)	Percent rooting
0	0.0
5	7.0
10	27.0
15	73.0
30	43.0

[z]Means represent 30 shoots/treatment.

Although the methods presented here are far from perfected, they work not only on shumard oak but also on water oak (*Quercus nigra*), pin oak (*Quercus palustris*), and live oak (*Quercus virginiana*). Work is being continued and procedures will soon be completed for mature oaks.

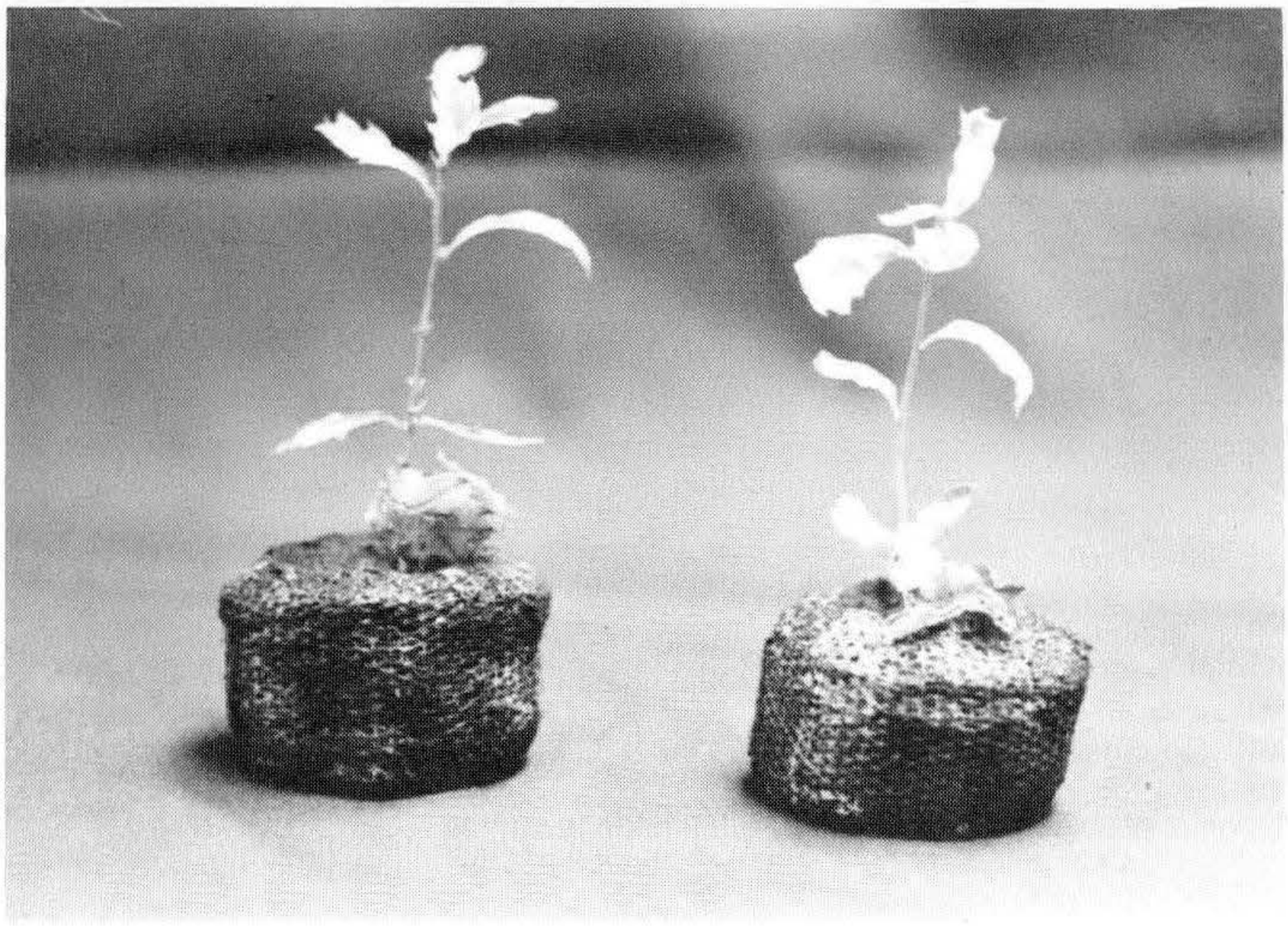

Figure 2. Shumard oak rooted in Jiffy-7 pellet after 15 min. dip in 500 ppm IBA.

REDBUD TISSUE CULTURE

Redbuds are another woody species that will soon be appearing on tissue culture price lists. A selection of *Cercis canadensis* from Mexico with thick wavy leaves and a weeping habit has been successfully cultured on WPM with 5 mg/liter BA (Figure 3). Shoot growth is extremely rapid and sectioning is often required monthly to prevent crowding. These plants have been in culture for over 2 years with no apparent ill effects.

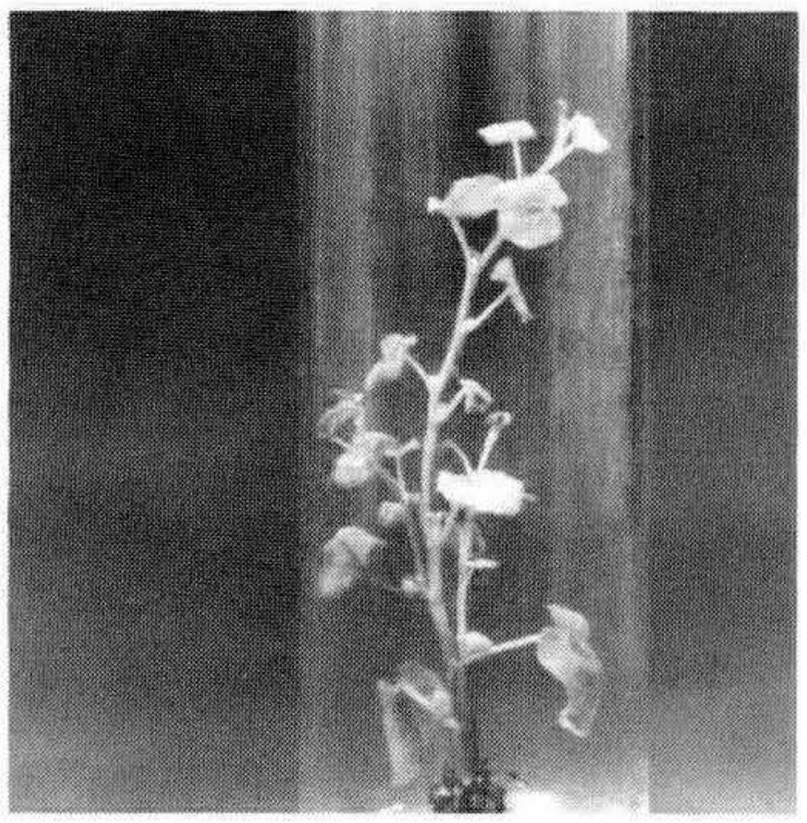

Figure 3. Shoot growth of *Cercis canadensis* var. *mexicana*.

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ASEXUAL PROPAGATION OF FRUIT AND NUT TREES AT STARK BROTHERS NURSERIES

ELMER L. KIDD, III

Stark Brothers Nurseries and Orchards Co.
Louisiana, Missouri

Stark Brothers Nurseries is 170 years old and produces 2 million trees on 2000 acres. The company is most noted for its Red and Golden Delicious apples, which account for 60 percent of total production.

At Stark Brothers we employ the following four asexual propagation techniques in combining scions to stocks:

1. T-Budding
2. Chip budding
3. Bench grafting (whip and tongue)
4. Crown grafting (whip and tongue)

All understocks used by Stark Brothers are purchased as liners from outside vendors except for peach and nut understocks, which we propagate as seeds obtained from both in-house and external sources.

Scionwood is obtained exclusively from our in-house scion orchard blocks, which are maintained as non-fruiting, hedgerow trees. Budsticks are cut and de-leafed one day prior to being used. Our budding season runs from early July through late September. Dormant wood to be used in our winter bench grafting and spring crown grafting operations is harvested from the scion orchards in early December.

Table 1 shows the various understocks used by Stark Brothers, the scion types propagated to these understocks, the propagation technique used for the various combinations, and the number of years following propagation that are required to bring the trees to salable size. Salable size is considered to be a branched tree with ½ to ¾ in. caliper in most cases.

Our T-budding technique is fairly standard. As scion sticks are de-leafed, a small portion of the petiole is left attached to the bud base to facilitate the handling of the bud shield as it is removed from the stick and placed in the "T" cut on the rootstock shank. Scion sticks are wrapped in burlap and kept cool and moist. Depending upon the kind of rootstock, the bud shield is placed in the rootstock anywhere from two to six inches above the soil line. T-buds are quickly wrapped with elastic budding rubbers which are left in place for approximately 14 days. A good budder will bud in excess of 1,800 buds in an eight hour day and a 90% bud stand or "take" is considered excellent. The T-budding of peach and nectarine in early July marks the start of our summer budding operation. We do not produce any June-budded trees.

Table 1. Asexual propagation scheme for fruit trees at Stark Brothers Nurseries.

Rootstock	Scion cultivar types	Type of propagation	Years to harvest salable trees
Seedling apple *Malus pumila*	apple	bench graft	2
Clonal apple *M. pumila* 'Mark', 'EMLA 7', 'M 7A', 'EMLA 9', 'EMLA 26', 'EMLA 111', 'EMLA 106'	dwarf apple	chip bud	1
Seedling pear *Pyrus communis* 'Bartlett' *Pyrus calleryana*	common pear Asian pear	chip bud	1
Clonal pear *P. communis* 'OH × F 333', 'OH × F 97'	common pear Asian pear dwarf pear	chip bud	1
Seedling quince *Cydonia oblonga* 'Provence'	dwarf pear	chip bud	1
Seedling peach *Prunus persica* 'Lovell', 'Red Leaf', 'Nemaguard'	peach nectarine	T-bud	1
Seedling prunus *Prunus tomentosa* *Prunus besseyi*	dwarf peach dwarf nectarine dwarf plum dwarf apricot	chip bud	1
Seedling cherry *Prunus mahaleb* *Prunus avium*	sweet cherry sour cherry	chip bud	1
Clonal cherry *P. mahaleb* × *P. avium* 'M × M 14' *P. avium* × *Prunus* *pseudocerasus* 'Colt'	dwarf sweet cherry	chip bud	1
Seedling plum *Prunus americana*	European plum/prune Japanese plum	chip bud	1
Clonal plum *Prunus insititia*, 'St. Julian A', 'St. Julian ×'	dwarf plum dwarf peach dwarf nectarine dwarf apricot	chip bud	1
Seedling apricot *Prunus armeniaca* 'Manchurian'	apricot	chip bud	1

After the peaches are T-budded, the balance of our budding operation shifts to chip budding. We find that, except for peaches, chip budding provides us with better stands and a straighter, more uniform tree growth. In collecting bud sticks for chip budding, it is important to match the caliper of the budstick with the caliper of the rootstock shank. Leaf petioles are completely removed from sticks used for chip budding.

In the chip budding procedure the receptive cut on the rootstock is made first. This requires two cuts. The first is made to a

depth of about ⅛ in. at an angle of 20 degrees to the stem to form the basal lip of the cut. The second cut is made 1½ inches above the first, entering the stem at the same 20 degree angle and then cutting down to meet the base of the first cut. In similar fashion, a chip of matching scionwood is cut from the bud stick and placed in the receptive cut on the understock. The length and width of the scion chip should be slightly less than the chip of understock it replaces. It should never be larger. The lip of the receptive cut holds the scion chip in place until it is wrapped.

We use ½ × 12-in. strips of clear 4 mil polyethylene to secure the scion chip to the understock. The material we use has a slightly elastic quality that allows for a more secure wrap. The bud is completely covered in all cases, except for cherry buds which are allowed to protrude from the wrap. Bud unions are usually sufficiently callused in 30 days, at which time the plastic wraps are removed. A good budding team can place and wrap 1800 chip buds in an eight-hour day. Bud stands often approach 100 percent and those buds that fail to "take" are rebudded to fill out the stand.

Stark Brothers grafters produce 750,000 bench grafts each January. To accomplish this feat, individual grafters are expected to make in excess of 1,600 grafts per day. The grafter first cuts a pile of 100 scion sections containing five buds each. The scion sections are then matched in caliper to a 4½-in. section of seedling root and the two are grafted together via a standard whip-and-tongue graft. Generally, two root sections can be obtained from each seedling rootstock. The grafts are then tightly wrapped with a biodegradable cloth tape, boxed in crates filled with moist excelsior and held at 70°F for 10 to 14 days to complete callusing of the graft and then stored at 34°F until being lined out in the nursery row in April. Success in callusing the graft is almost always better than 98%, but additional losses are incurred when 10 to 15 percent of the grafts fail to transplant successfully.

Our crown grafting procedures are best exemplified by our walnut propagation efforts. Stark Brothers is currently propagating and marketing a total of 15,000 grafted walnuts each year. The species propagated are *Juglans nigra,* (black walnut), *Juglans regia* (English or Persian walnut), and *Juglans cinerea* (butternut or white walnut). All three species are crown-grafted to two-year-old eastern black walnut (*J. nigra*) seedlings which are selected for their vigor, hardiness, and desirable root system.

Our procedure calls for the cutting of the understock three to 10 days prior to grafting the scion cultivar. The timing of the grafting operation is determined by the cessation of sap bleeding and the anticipated weather conditions at and shortly after the time of grafting. When conditions are right for grafting, ⅜ to ⅝-in. caliper scions are grafted to the seedlings, wrapped with masking tape and then tented with aluminum foil for 10 to 20 days, until shoot growth

approaches 1-in. in length. This technique regularly yields a success rate greater than 90 percent and finished trees in the three- to four- (two- to five-) foot range. Recent tests with rose wax indicate that dipping the scions in wax prior to grafting may eliminate the need for the aluminum tenting.

HANDLING TISSUE CULTURE PRODUCED LINERS

JAIME E. LAZARTE and CAL A. FROBERG
Plant Reproduction International, Inc. (PRI)
20835 Broze Road
Humble, Texas 77338

Abstract. Quality, competitive prices, and customer service are a must in the tissue culture industry. Quality includes health, branching, size, true-to-name, labeling, packing, and shipping. Stage II and III plants should be planted as soon as they are received and should follow a 4-week acclimatization procedure. Stage IV plants should be watered and placed in a shaded area as soon as they arrive. Transplant Stage IV plants as soon as possible.

The tissue culture industry started approximately 15 years ago. However, research in tissue culture dates back to the 1890s. Since then advances have been made in improving propagation, increasing production, developing new types of plants, and in producing disease-free plants.

There are a handful of laboratories above 15,000 square feet and many small operations around the country. At Plant Reproduction International, Inc. (PRI) we have an 18,700 ft.^{2} facility, which includes research and production laboratories. Our average capacity is 24 million plants per year. We have occupied our new facility for a year and our present inventory is 800,000 plants. Our goal is to reach 1.5 million plants in production by 1987.

Products and marketing. Tissue culture laboratories have had a non-competitive market for their products until two or three years ago, when two large tissue culture labs were started, one of them PRI. At present there is a market for tissue-cultured plants with better plant quality and competitive prices. Such competition is favorable for the growers and for the labs that know how to do it right. PRI visualizes that in the future the marketing competition will be much like the fashion industry, focusing on new, high quality, and competitive-priced products. It is for these reasons we emphasize research and development.

Our research department is currently working on introducing different types of plants into tissue culture, especially woody plants, and developing procedures for new introductions. PRI's research goals include short, mid- and long-term objectives in areas

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such as clonal propagation, mutagenesis, *in vitro* fertilization, embryogenesis, anther culture, and callus culture.

At present we are working on over 35 different plant species totaling over 100 cultivars. Most of these plant species have never been propagated by tissue-culture techniques. Some of the species we plan to release soon are: compact cherry laurel, red bud, purple smoke tree, and water oak.

We are also producing woody plants that already have tissue-culture procedures worked out and published. Nandinas, rhododendrons, roses, blueberries, and daylilies are a few that are currently in production. Some of the other plants currently offered by tissue culture companies include alocasia, anthurium, apple rootstocks, azaleas, banana, Boston ferns, blueberries, daylilies, dieffenbachia, *Ficus* spp., gerberas, heliconia, kalmia, liriope, nandina, orchids, philodendron, rhododendrons, roses, schefflera, spathiphyllum, and syngonium.

Tissue culture stages. Tissue culture is a term that designates techniques used to grow explants in sterile cultures. There are four stages in plant tissue culture:

Stage I —Establishment
Stage II—Multiplication
Stage III—Rooting
Stage IV—Acclimatization

Most plants are sold as Stage IV—acclimatized liners. However, some are sold as Stage II—non-acclimatized, unrooted microcuttings, or Stage III—non-acclimatized, rooted microcuttings.

Products Stage II and II. After establishing the explants in a multiplication media, clusters of shoots are dissected in a transfer room under a sterile transfer hood. From one cluster it is possible to obtain from 5 to 20 shoots depending on the species. At this point larger shoots can be harvested as stage II unacclimatized, unrooted microcuttings, and the smaller are recultured for multiplication. Another possibility is to divide a cluster into smaller clusters for Stage III unacclimatized microcuttings or potting in the greenhouse. All tissue-culture plants should be graded (first selection) according to size, since tissue-culture shoots are not necessarily of the same size, e.g. dieffenbachia, syngonium, spathyphyllum, nandinas.

Plants for reculture go back to the growth room. Most growth rooms are maintained at 75 to 78°F with a 16-hour photoperiod.

It is good to see that the tissue-culture industry is improving the boxing and packing of their products. Stage II and III are being shipped in designed boxes; packing varies from newspapers to styrofoam boxes or styrofoam beads. Individual containers used are polybags, presspaper boxes, aluminium boxes, or plastic boxes.

The product should be uniform and of good size 1 to 1.5 inches. It should be either a microcutting or cluster, according to order, and should be clean of agar. Some labs ship with agar and do not select

their product. The main problems are uneven flats and plants with excessive callus that could lead to decay.

For stage III plants, shoots are rooted in the test tubes or as a regular cutting. In any case, before planting, plantlets should be rinsed with water to clean the agar or medium from the plantlet.

Several types of trays are used for planting. Most are styrofoam trays with 24 to 200 cells. These trays are inconvenient because of their size and cost. We have received tissue-cultured plants of several cultivars packed in one box, all mixed up. The plugs were out of the cells and many times there were no labels or the labels were out of place and mixed up.

Flexible trays are a problem for shipment. The most widely used are those with a rigid edge, which come in a variety of sizes including 72-cell, 96-cell, 200-cell, and 288-cell trays. Some trays have a round cell and others have square cells.

We have tried several commercial mixes and we were able to get only one that has a peat:perlite mix for plugs. This mix is used for foliage plants but it retains too much water for woody plants. Woody plants require a mix with better drainage. We are testing a bark:perlite and a bark:peat:perlite mix. There are also sponge and rockwool products.

Acclimatization. When microcuttings are received they should be graded for size (second selection) and planted immediately in a shaded area and placed under high humidity conditions and shade. The reason for this is that the plants are grown in closed containers and are susceptible to wilting. Acclimatization follows a series of changes to lower humidity and increased light for hardening off. This process takes approximately four weeks.

There are several ways to accomplish acclimatization. Humidity tents on individual trays, plastic covers on individual trays, or tents over beds are all satisfactory. The source of water could be a regular mist system or a fog system. The end product should be completely hardened for regular growing conditions.

Product—Stage 4. Stage IV trays should be inspected for empty cells, size of shoots, health and color before shipment in order to guarantee higher quality. This is the third selection that tissue culture plants undergo. A case generally consists of 144 plants and should include a growing recommendations sheet. All trays should be correctly labeled.

In a box there is a division and 2 holders to secure the trays in place and to avoid crushing of the plants. When plants are received they should be potted as soon as possible under the recommended conditions. Nandinas should be planted directly in the field for field container production and the same procedure should be followed for any other outdoor plant. Foliage and greenhouse plants should be planted under conditions for greenhouse crops.

Advantages of tissue culture liners. Growers should enjoy

advantages of tissue culture, such as:

1. Uniformity
2. Programming of crops
3. In some species, better plant branching resulting in better products
4. Disease-free plants
5. Availability

Our goal should be for quality, efficiency, and customer satisfaction. Tissue culture is a useful technique for propagation in the horticulture industry and should not be blamed for the subsequent mishandling by producers and growers.

QUESTION BOX

Moderated by Carl Whitcomb and Bryson James

JOE POWELL: David, do you use lime in your propagation mix?

DAVID SABALKA: No. As Carl Whitcomb has pointed out, we can pick up all we need from other sources, such as water.

RICHARD ODOM: Have you tried rooting using Micromax, but no Osmocote?

CARL WHITCOMB: Yes. However, I do not recommend using Micromax unless you also use at least 4 lb. Osmocote 18-6-12/yd.^{3} Start out at the low rate. Also, be careful about mixing large batches as Osmocote may begin to release. We have found supression of rooting when most other fertilizers or formulations of Osmocote were tried and therefore use only 18-6-12 Osmocote.

RICHARD ODOM: When do you begin to see trouble from Osmocote if the rate or application method has been wrong?

DAVID SABALKA: It depends on the watering and soil temperature. We don't ordinarily have problems in the winter. Most of the time toxicity problems will show up within the first four to six weeks.

JIM BERRY: What is a dangerous salts level?

BRYSON JAMES: If the mix is 2:1 bark:perlite, no fertilizer is needed at first; 18-6-12 Osmocote doesn't release for about three to four weeks, which is about right. A salts level higher than one micromho is too high in a 2:1 mix. There are many methods of testing and expressing soluble salts concentrations. It is important to use one method consistently and monitor changes. Once you determine the level at which your plants do best, that level can be used as a guide for making needed adjustments in fertilizer pro-

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grams from time to time.

GARY TAYLOR: Do you use wetting agents in the mix?

DAVID SABALKA: Yes, but they are expensive. I prefer to avoid them if possible.

BRYSON JAMES: It is better to change the medium or the mist cycle than to depend on wetting agents.

CARL WHITCOMB: When David was describing his mixes, I thought, "Remember, his material is a particular combination of particle size, which will change the air space even though the ingredients and their ratio may be the same as that of some other propagator." Drainage depends on the depth of the pot and the physical characteristics of the medium. When the same growing medium is placed in containers of varying depth, as the container depth decreases, the proportion of well-drained growing medium also decreases.

DAVID JOHNSON: Will it matter what the container is sitting on?

CARL WHITCOMB: If there is any break between the medium in the container and the material on which it is sitting, the effects of particle size of the mix and pot depth will the the same as just described. If you use a capillary mat and get good contact, you can actually pull out excess water. The problem is that the roots will grow into the material. A small particle-size material below the container will pull out water better than a coarse one. The simplest thing to recommend to a person having trouble is to use a deeper pot. In all cases, of course, you must have a mix that does not fall apart during transplanting because of too much pore space. The material should remain with the roots when the plant is transplanted.

BRYSON JAMES: Don't make too big a handle on the cutting by removing bottom leaves. The propagators then tend to stick the cuttings too deep where they are in the saturated soil zone of the container.

CHARLES COX: What is wrong with pure bark for a rooting medium?

CARL WHITCOMB: It is often used. In my own case, I just don't get as good subsequent growth.

DAVID SABALKA: We find we can grow in 100 percent pine bark, but the plant often has trouble in the landscape later.

CHARLIE PARKERSON: Ted Richardson grows only in bark.

TED RICHARDSON: I have been using pure bark for 15 years and have found nothing to improve it. I seem not to have much control over the man loading the dump truck. I say I want ½-in. screen, but probably ¾-in. is just as good.

JOE POWELL: Fine bark did not work for us, but a coarser grade was also unsatisfactory. However, when we added a little sand, it worked quite well.

CHARLES COX: What about sand?

BRYSON JAMES: Straight pure sand is fine if it is clean. Particle size is important. The question is what you are going to do with the liner. It is best to have the rooting medium as nearly as possible like what it will eventually be growing in. Often sand is added just to keep containers from blowing over. Frank Pokorny, University of Georgia, has done a great deal of research on particle size of pine bark and would be glad to send you a list of his papers. I have better luck adding some other material to improve drainage. I recommend that pine bark be ¾-in. particle size and smaller.

MICHAEL DIRR: What about root cubes? We have used them and had no interface problems.

TED RICHARDSON: We have found that if you plant a cutting in a root cube and don't give the cutting specific aftercare, there will always be an interface.

DAVID BYERS: Unless the roots are clear out of the cube, the cutting has trouble surviving. The cube often dries out while is it impossible for the plant to pick up water from the surrounding medium.

PETER VAN DER GIESSEN: The most important of all is the cutting itself and how deep it is stuck.

CHARLIE PARKERSON: Is blending Osmocote into the propagation mix a problem? We have been top dressing for fear we do not get an even distribution when we mix it in.

CARL WHITCOMB: We prefer incorporation to avoid algae growth on top of containers.

GARY TAYLOR: Cariedda, how often does your fog come on?

CARIEDDA HUDGENS: When the temperature outside is 90°F., the fog stays on almost all day. As the days get shorter, the time of day when it turns on and off are later and earlier. With our fog nozzles 7 feet above the plants, in summer it goes off perhaps five times a day.

QUESTION TO MICHAEL DIRR: Does it matter whether you take cuttings from stock or sales plants?

MICHAEL DIRR: Sales plants are usually too high in nitrogen, which makes the carbohydrate balance not the best for rooting.

BRYSON JAMES: There are also other factors involved. Someone from Greenleaf Nursery has said they have found cuttings were weaker as they were taken from plants farther removed from the original parent.

RANDY DAVIS: *Prunus* species will not root for us when taken from our sales plants. We get 2 percent rooting of the cuttings taken from sales plants but 95 percent of those taken from stock plants.

QUESTION FOR MICHAEL DIRR: We get heavy callus and no roots on Raphiolepis, Cleyera, and Photinia cuttings. What do you suggest?

MICHAEL DIRR: Increase the hormone level and watch your watering.

BILL BARR: We use 25000 ppm IBA and 2500 ppm NAA for *Raphiolepis;* 10,000 ppm IBA for *Photinia,* but no hormone for *Cleyera. Cleyera* takes 6 to 9 months to root, however. Our mix is 50 percent bark, 25 percent peat, and 25 percent sand.

There was also a question earlier as to the time to stick dwarf yaupon holly. We stick cuttings in December, January, and February and mist lightly. We use only a light hormone treatment.

MARK HOUSE: We have noticed leaf burn on cuttings of dwarf yaupon cultivars when we used IBA in alcohol. We now use K-IBA and take cuttings in May and June and get 85 percent rooting.

BILL BARR: We use bottom heat, a perlite medium and 1800 ppm IBA. We get 80 to 90 percent rooting. We have found no burn from K-IBA.

JUDSON GERMANY: Probably the cuttings of yaupon holly could be taken just about any month. I believe the trouble is sticking too deeply and using too much water.

JIM BERRY: We find the optimum time to take cuttings is in October when the summer heat breaks and we can stick cuttings in the greenhouse. We use 1875 ppm IBA in alcohol although I actually like to use 3000 ppm in water. The caliper of the cutting is important. We use a bushy cutting and leave a branch ¾ inch from the bottom. This keeps the propagators from sticking the cuttings too deep.

DON COVAN: Has anyone else had a problem with Rout ornamental herbicide? We have noticed an effect on crape myrtle, photinia, and dogwood.

RICHARD ODOM: We were concerned about using Rout and talked with company representatives who said it is not economically feasible for them to do the research on each ornamental species. If enough growers contact the company requesting it, they will do the research.

CARL WHITCOMB: I believe it is the Surflan in the Rout that is causing the trouble.

RICHARD ODOM: The company researcher said that the Surflan is much more soluble than Goal and that because of this it is a volume, or concentration, effect. These people say that as long as the plant is well-established, Rout is safe.

CHARLES GILLIAM: Both Scotts and Sierra have removed crape myrtle from the label and are testing Surflan. I have found that Surflan definitely affects rooting of Japanese holly. Helleri holly is back on the label this year, however.

BRYSON JAMES: Has anyone had problems with Truban?

GARY TAYLOR: We didn't get any rooting in our rhododendrons when we used Truban.

TED RICHARDSON: In answer to a question about using Alliette fungicide I would say that it is more or less all right to use although I have not done any real testing.

TED GOREAU: We have used Alliette for about a year with mixed results. I have not felt it was especially effective in controlling *Rhizoctonia*. It seemed to me that azaleas did not do well after using Alliette on them. I think a good basic fungicide program is important.

JIM BERRY: We use primarily Benlate and Zyban fungicides and Orthene insecticide in our basic program.

CHARLIE PARKERSON: Last year at this meeting we discussed the problem of azaleas breaking off at the soil line. It seems to be a physiological problem, perhaps just the result of creased roots in the bottom of the container. We noticed the problem long before we began using many of these chemicals, so I don't think we can blame them. It may be just a series of other factors. Maybe cold weather almost, but not quite, causes bark split. The problem is industry-wide. Some cultivars are more susceptible, but none are completely immune. It does seem to move through a planting. As yet there aren't any answers.

CARL WHITCOMB: I have been asked about using concrete above heating pipes in order to even out the distribution of bottom heat. It has been reported that the concrete really did not help that much.

CHARLIE PARKERSON: We find that the porous concrete works much better.

MICHAEL RICHARD: We have 4 inches of concrete over our heating pipes and are getting even distribution. We are using 100° to 120°F water.

STEVE NEWMAN: I have been asked whether or not plants feel wind chill in the same way as humans. They do not. However, they do desiccate because of the wind.

CARL WHITCOMB: Wind around containers removes heat, of course.

CHARLIE PARKERSON: There was a question about the effect of white rock or white poly ground cover under the pots. White on the ground will increase heat around the container but the white container will keep the plant roots cooler.

CARL WHITCOMB: There has been a question as to how long plants can grow in the field in the fabric containers. It depends on the plant itself. Eventually the restricted root growth will restrict top growth as well.

BRYSON JAMES: How long you keep it in the field will depend on the market. I agree with Carl that the restriction is no greater than it would be in a pot.

GARY TAYLOR: Is foliar feeding effective?

BRYSON JAMES: It is mainly useful for stimulating plant

growth in the short term. It is not good for an all-around method of applying fertilizer.

DAVID JOHNSON: We are finding high pH readings in pine bark. We have high mounds of bark that are not really ageing, so are developing some toxicity.

CHARLIE PARKERSON: We threw away our pH meter. As long as the Ca:Mg ratio is okay, pH seems not to matter. I don't believe high pH itself is the problem; high pH is just an indicator that something else may be wrong.

IMPORTS AND EXPORT PROCEDURES: THE ROLE OF THE MINISTRY OF AGRICULTURE AND FISHERIES

ROSALIE J. HECKLER

Ministry of Agriculture and Fisheries
Batchelar Agriculture Centre
Palmerston North

Most crop pests, diseases, and weeds established in New Zealand have originated overseas. Many more could still be introduced on imported plants and plant products. New Zealand has the advantage of excellent geographical isolation which acts as a natural barrier to the spread of parasites.

Most diseases and many pests have been carried here by man. Some exceptions are rust diseases and insects which have blown across the Tasman Sea from Australia.

The Ministry of Agriculture and Fisheries (MAF) quarantine role is to prevent the entry into New Zealand of unwanted parasites not already established here. This cannot be done alone so cooperation is required from the industry and the travelling public.

Legislation under which MAF controls plant imports and quarantine include: The Plants Act 1970, Introduction and Quarantine of Plant Regulations 1973, and The Noxious Plants Act 1978.

IMPORTING

Anyone may import nursery stock, bulbs, corms, etc of ornamental plants, as well as most seeds and cutflowers, subject to the conditions in the regulations.

Nursery stock (whole plants, cuttings, budwood) is divided into two main categories: *Closed Quarantine,* and *Open Quarantine.*

Closed Quarantine. This is for plants of great economic importance and those which are on the prohibited list. Crops included in this system are berryfruit, citrus, many conifers, grapes, potatoes, pip and stonefruit. Very small quantities of new cultivars of this type of nursery stock are imported and usually quarantined in Auckland. Parts of the original plants, if clean, are later released to the industry. The conditions and time intervals for closed quarantine are many and varied.

Open Quarantine. This system is for most other classes of nursery stock which include several thousand species of plant. These plants present less of an economic risk and their importation is subject to a less intensive quarantine procedure.

Nursery stock allowed entry into New Zealand through open quarantine may be imported provided several conditions are met:

- A prior permit to import is obtained from MAF, New Zealand, and is with the plant on arrival at the point of entry.

- The consignment is accompanied by an International Plant Health Certificate, with the necessary endorsements. This is to be issued in the country of origin of the plants.
- The nursery stock on arrival is to be free from pests and diseases.
- The plants are to be grown for a period in quarantine after arrival in New Zealand.

General Nursery Stock. Nursery stock for growing has a potential quarantine risk as the parasites are already in contact with their hosts. These can easily become established when the host is moved to another area. For this reason, the plant material is detained in post-entry quarantine on arrival and checked for any latent infection or infestation. Under the open quarantine system the minimum quarantine period ranges from three months for orchids to two growing seasons for roses.

Bulbs, corms, tubers and rhizomes of ornamental plants may be imported provided they are dormant, free of soil, pest and disease, and are accompanied by a health certificate. Generally, no prior permit or detention in post-entry quarantine is necessary.

Exceptions are:

- Begonias, paeonies, and orchids. They are classed as general nursery stock and subject to quarantine.
- Gladioli, rhizomatous irises, lilium spp. and tulips. For these, the accompanying health certificate must contain an endorsement: "That the bulbs, corms, tubers were obtained from plants inspected during the previous growing season by the appropriate government organisation and found to be free from pests and diseases, including virus diseases".

Some nursery stock does not require an import permit or any detention in quarantine. These include:

- Orchids and some other ornamentals growing in flasks under sterile conditions. They should be accompanied by a health certificate.
- Alocasias and colocasias.
- Coconuts.

Importer's Role. It is up to the importer to provide the suitable post-entry quarantine site. An import permit will not be issued until this requirement is met.

While in quarantine, the plants must be given optimum growing conditions and may not be moved or propagated without prior permission of MAF. Importers are restricted to the number of plant units that they may import at any one time or in one year.

- Plants arriving without an import permit will be either destroyed or reshipped at the importer's expense.

MAF's Role, Now that I have given you a broad overview of the quarantine system in New Zealand, I will outline where MAF fits in. MAF has a major role in the

importation of plants which is to:

- Receive the import application;
- Check the quarantine site and authorise the application;
- Issue the import permit;
- Inspect the plants regularly while in post-entry quarantine;
- Release the plants when the quarantine period has been observed.

In summary, MAF's role is to help prevent and intercept any new pest or disease that may enter New Zealand on plant material.

EXPORTING

MAF's role in the export of plants and plant products is to:

- Interpret the importing country's plant health requirements.
- Ensure that these requirements are met.
- Provide certification to MAF's counterparts overseas.

This involves:

- Establishing acceptable quarantine levels and informing the industry.
- Advising exporters of any changes in the quarantine requirements of respective countries.
- Preparation of export spray programmes.
- In conjunction with the industry the setting up of acceptable quality levels.

Quality Assurance. Perhaps the most important MAF role relates to quality assurance of export products. This involves ensuring that the quality of the product is monitored throughout all stages of the production chain, from the grower through to the exporter and the overseas market. Early detection and accurate identification of problems in the production chain saves time and money, and is important in guaranteeing a quality product. Quality assurance is market led rather than production driven. It is the suitability of a product for a purpose. Horticultural products should be tailored to what the market wants rather than what we want to produce or have already produced.

Export Certification. Once MAF is confident that the plants or plant products to be exported have reached the required standard, an International Plant Health Certificate will be issued to the exporter. This is a government-to-government document issued under the International Plant Protection Convention. This certificate states that the produce at the time of inspection met the requirements of the importing country. It is valid for only fourteen days.

General Information. People considering export should check with MAF as soon as they receive an initial enquiry. This is particularly important with nursery stock as additional requirements may need to be carried out by MAF.

This may include one or all of the following:

- Inspection during the previous growing season.
- Plants may be required to grow in sterile media for a specified time prior to export.
- Soil analysis for soil borne pests and diseases. For example: Potato Cyst Nematode.
- An export spray programme may need to be followed.

In conclusion, I would like to say that New Zealand's ability to develop and maintain overseas markets depends on its continued reputation of exporting quality plants and plant products, free from pests and diseases. The whole industry is responsible for maintaining this reputation. As I have only been able to cover both import and export in general principles, I suggest that if you have any further queries that you contact your nearest MAF office.

PRODUCTION OF *WASABIA JAPONICA* IN JAPAN

JOHN M. FOLLETT

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Hamilton

Wasabi (*Wasabia japonica* [syn. *Eutrema japonica; E. wasabi*] is a member of the Cruciferae family, a semi-aquatic native to the montane forest areas of Japan. Wasabi produces a stem, often referred to as a rhizome, in a similar fashion to a small brussel sprout. As the stem grows the lower leaf petioles fall off, and when the stem is about 15 cm long it is harvested.Traditionally, the stem is ground up into paste and used as a condiment with Sashimi (raw fish), Sushi (fish and rice) and Soba (buckwheat noodles). The best quality stems are sold fresh through the wholesale markets. In recent years wasabi has become more popular resulting in both the lower grade stems and leaf petioles being used for processing. At the Tokyo Central Wholesale Market processing wasabi sells for low prices and price premiums can only be obtained for high quality produce.

Wasabi is grown on all major islands of Japan except Hokkaido, and is also grown in Taiwan and North Korea.

In Japan the area planted in wasabi has remained fairly constant in recent years with changes being due mainly to typhoons damaging the wasabi beds. Japan's total yield varies from 2,000 to 3,000 tons/year.

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Wasabi requires an equitable climate with optimum growth at

an air temperature between 8 and 18°C, and a high even rainfall. It is produced both as a terrestrial and as an aquatic plant; 72% of the wasabi sold as fresh stems on the Japanese wholesale markets is grown in water with water quality playing an important role in producing crops of a high standard. Wasabi grows best in cool water and in Japan the water for growing wasabi is derived from springs as opposed to water from catchment runoff. The water must also be in constant supply, contain sufficient plant nutrients, and be free of organic contamination.

In Japan it was suggested that the regional geology and soils were significant in producing good wasabi. Quartz and basalt terrains were considered optimum.

Wasabi does not grow well in full light in summer with plants being shaded from April through to August. Shading was provided either naturally using deciduous black alders (*Alnus japonica*) planted evenly throughout the wasabi beds or by using shade cloth.

Propagation. Wasabi is propagated either by seed or by using offshoots from parent plants. Seed is used to eliminate virus build up and where it was not necessary to maintain a selected cultivar. Offshoots were used when it was necessary to maintain a selected cultivar. Propagation by tissue culture had been developed in Japan so that viruses can be eliminated while still maintaining the cultivar.

Seed propagation:

Wasabi flowers and produces seed during spring. Seeds are available for collection in May and June in Japan. They are usually stored until sowing in January and February. Germination normally takes about 2 weeks. Seed is precision sown by hand into carefully prepared nursery beds.

In about August in Japan (February in New Zealand) selected seedlings are lifted, washed, and the adult leaves removed with the petioles cut at about 5 to 10 cm from the stem. This allows for planting in September.

Vegetative propagation:

Offshoots which are broken from the main wasabi plant at harvesting are generally used for vegetative propagation. Harvesting can occur at any time of the year, however the main crop is produced from late spring to early autumn. When the mature wasabi plants are harvested they are lifted from the ground and the roots and lower stem cleaned. The offshoots which develop from the base of the stem are broken from the main stem, trimmed and the main leaves removed. The offshoots are then bundled ready for planting directly into a prepared wasabi bed.

Production Methods. In Japan three production systems were visited: (1.) soil cultivation, (2.) hydroponic production, and (3.) beds formed in and along small streams.

Soil Cultivation.

Approximately half of Japan's wasabi is grown directly in soil. A 30 ha farm in Nagano prefecture was visited to view this form of planting. Here the wasabi was being grown in mountain woodlands. Before planting either offshoots or seedlings the ground was cultivated and mature compost and phosphate fertilizers were applied. Nitrogen was not recommended. Before planting the leaves of the propagation material were removed and used as a mulch around the plants. On this particular property plants were left for up to three years before harvesting. Most of the harvested material from this property and others growing wasabi in soil was sold to the processing industry. Two crops were grown on the same site before the ground was fallowed for three years.

Hydroponic Production

Near Hotaka in Nagano Prefecture one grower was experimenting with wasabi in hydroponics. Wasabi was supported by ceramic pellets in a trough. No work had been done on specific nutrient problems; the grower used a standard hydroponic nutrient formula. There was, however, a problem with plants wilting when the temperature got above 20°C.

Beds formed in and along small streams

Stream beds were modified for growing wasabi in one of two ways. In larger braided stream beds, river gravel was mounded into herring bone designs with wasabi being planted on these mounds. In steeper country the stream beds were often terraced to provide growing beds for wasabi.

1. Mounded beds: One of the largest farms using the mounded bed system was situated at Hotaka in Nagano. This 15 ha property produced 300 tones of wasabi per year. The beds were arranged in herring bone fashion and carefully graded to allow for maximum water flow not only through the troughs between the beds but also through the beds, thus allowing for a maximum amount of water to pass around the root zone of the wasabi plant. Because of the small stream bed gradient, wasabi at this site was being grown on raised beds above the water level in order to allow for maximum water flow through the root zone.

At Hotaka the growing season using this system was approximately two years from final planting out of the seedlings. At harvest each seedling produced approximately 15 stems with a total plant weight of around two kilograms. The best stems were packaged for the fresh market but most was used by a thriving local processing industry.

2. Formed beds: The most important feature of the formed bed was that it allowed for water to pass over the bed around the wasabi stem. This allowed for a more even environment resulting in more growth of the crop.

There were three methods of constucting beds:

(a). The Keiryu style was used in situations where there was insufficient spring water to use either of the other two methods. Disadvantages of this system included uneven crop growth and quality and a long growing period. Because of a lack of water to help maintain an even environment this method was restricted to areas that experience cool summers.

(b). The Jizawa style was used in the Abe area of Shizuoka Prefecture. Beds were terraced and filled with small pebbles to a depth of 10 cm. Although water flow across the top of the bed was high thus helping to maintain an even environment, water flow through the bed was restricted resulting in uneven crops.

(c). The Tatimi ishi or "Stone mattress" style was used extensively in the Izu Peninsula are of Shizuoka Prefecture. This method of bed construction resulted in even cropping giving wasabi of very high quality.

The beds were about one metre deep. The drainage of water from the base of the bed was very important and drainage channels were constructed at the base of the bed, or alternatively, drainage pipes or field tiles were used. Boulders up to 60 cm across were laid to a depth of 40 cm with stones and pebbles on top of them with the size of the material decreasing as the height increased. The top 10 to 15 cm of the bed was river sand. Once constructed these beds should last for 15 to 20 years.

A property in Izu Peninsula using the tatami ishi style of bed construction was visited. There were 12 ha of wasabi in several adjoining valleys. Twenty-five people were employed. Spring water which appeared along the cliff face was collected in channels and diverted onto the wasabi beds. After passing through one or two beds water was then channeled to waste. Waste and flood water was collected in a large central channel running down the centre of the valley. Between the collection and flood channels wasabi beds were constructed wherever possible. Water from the collection channels was diverted to the wasabi beds using a range of interconnecting channels and pipes. Harvesting was done in June and July with plants being lifted, cleaned, with the side shoots kept to establish the next crop.

Pests and Diseases

For successful wasabi cultivation the control of diseases was of prime importance. Wasabi, like many other cruciferae, was host to a wide range of diseases which can cause serious crop losses.

The worst diseases were those caused by *Erwinia* spp. and *Phoma* spp. Both diseases affect the stem thus having a severe affect on crop returns. There was also no economic chemical means of controlling these diseases. Thus attention should be paid to maintaining good crop hygiene and a good growing environment for the wasabi.

Caterpillars and aphids were regarded as the worst pests

(aphids because of their role in transmitting virus disease). The Japanese recommend spraying an insecticide 4 times during the summer.

Post Harvest. Wasabi for the fresh market was packed into 2 or 4 kg wooden boxes. The 4 kg boxes were traditional, but there has been a trend in recent years to use 2 kg boxes. Wasabi for the fresh market was transported as flat cargo on trucks to the wholesale markets. Tokyo market receives produce from all over Japan and in some cases this can take up to three days between harvesting and arriving at the market.

Relevance to New Zealand. Fresh wasabi stems have a high profit profile when sold on the wholesale markets in Japan. Although wasabi is a robust plant and will grow in a wide range of environments the conditions necessary to produce a high quality product are specific. The most important factors are an equitable climate and a constant supply of clean cool water. Many areas of New Zealand have both a climate and water supply that would suit wasabi production.

Other factors that should be included but may not be critical include land contour for good drainage, nutrient status of the water and light requirements. These factors can all be modified to suit the crop so should not prove a problem to establishing an industry in New Zealand.

Acknowledgements: I am indebted to the Winston Churchill Memorial Trust for a fellowship and Turners and Growers Exports, Limited, and New Zealand Trade and Industries Department, for financial assistance to visit Japan.

PROPAGATION OF *LIMONIUM PEREGRINUM*

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Abstract. *L. peregrinum* propagates readily from cuttings stuck in a very free-draining medium. Micropropagation was successful using a modified Linsmaeir and Skoog medium containing naphthaleneacetic acid, benzyladenine, and low sugar. Rooting occurred on modified Linsmaeir and Skoog medium containing indole-butyric acid and relatively high sugar. The efficient propagation of this plant will allow its use in cut flower production.

INTRODUCTION

The genus *Limonium* is characterised by flowers with a long vase life. Frequently the flower passes from a fresh to a dried state in the vase, suffering very little change in either colour or form. The durability of these flowers makes them suitable for export to distant markets. Over the past three years we have investigated several *Limonium* species for cut flower production at Levin.

Limonium peregrinum, a native of the coastal Cape region of South Africa, has shown promise in a preliminary screening of the genus. The striking pink flowers of this low growing perennial are being assessed for their potential as cut flowers. Plants of *L. peregrinum* growing in gardens around New Zealand were located and cuttings brought to Levin for assessment. Up to 20 years ago it was sold by some nurseries in New Zealand, propagation being largely by seed. As the species became rare in the wild and the seed became more expensive, nursery production of this plant declined. In this paper we describe studies of both conventional cutting propagation and micropropagation as alternative methods of rapidly propagating this plant.

CUTTING PROPAGATION

Tip cuttings (50 mm) of one clone collected from a garden near Levin, unwounded, and dipped in IBA (0.3% in talc) were stuck in each of the following media:

(1) Fine grade pumice (2 to 3 mm)
(2) Medium grade pumice (5 to 7 mm)
(3) Sharp river sand
(4) 1:1 fine bark ("Fibremix")/medium pumice
(5) Fine bark ("Fibremix")

Cuttings were placed under open mist with 21°C bottom heat. Mist was controlled by an automatic sensor. Experimental design

was a randomised block with six replicates and 10 cuttings per replicate.

Assessment: Each replicate (10 cuttings) was weighed at the beginning and conclusion of the experiment. Each cutting was visually assessed for root formation after eight weeks.

MICROPROPAGATION

Cultures were initiated from vegetative nodal segments taken from mature plants. Segments were placed on Linsmaeir and Skoog (LS) medium supplemented with 0.05 mg/l indolebutyric acid (IBA), and 0.3 mg/l benzyladenine (BA). Shoots arising from these segments were transferred on to modified LS medium containing twice the iron concentration, 0.3 mg/l naphthalenelacetic acid (NAA), 0.6 mg/l BA, and 10 g/l sucrose. For root development, individual shoots were transferred to a modified LS medium with macro inorganic compounds reduced by half, 0.3 mg/l IBA, and 30 g/l sucrose. Plants were exflasked into a free-draining, fine pumice medium under intermittent mist.

RESULTS AND DISCUSSION

Cutting Propagation. Strong, well-rooted plants resulted from cuttings stuck in a free-draining relatively dry medium. The highest number of plants rooted in the medium grade pumice (Table 1), significantly more than in the other media (at the 5% level for fine pumice and fibremix/media pumice, and 1% level for sand and "Fibremix"). The number rooted in "Fibremix" alone was significantly (5%) lower than in all other media except sand. The increase in fresh weight showed a similar trend to the rooting number. Interestingly, the medium with the greatest water-holding capacity ("Fibremix"), gave the lowest fresh weight gain, although a high proportion (94%) of cuttings in this medium were still alive.

Table 1. Cutting Propagation of *Limonium peregrinum*. Ten cuttings per replicate.

Medium	Mean number of cuttings rooted	Mean F.W. Increase
Fine pumice	4.7	5.8 grams
Medium pumice	7.3	10.9
Sand	3.2	4.5
Pumice/Bark ("Fibremix")	4.0	1.3
Bark ("Fibremix")	1.0	−0.3

S.E. = 2.26; LSD (1%) = 3.71; LSD (5%) = 2.72

Micropropagation. Initial attempts at micropropagation were relatively poor. A bacterial contaminant (*Erwinia* sp.) was identified on a peptone enriched bacterial medium although contamination was not visible on the micropropagation media. The plant material was freed from the contaminant by repeated subculturing on media containing streptomycin, then checked for contamina-

tion by streaking plant material on bacterial media. "Clean" material showed a six-fold increase in shoot numbers every six weeks on the proliferating medium. The majority (75%) of shoots transferred to the rooting medium had produced roots after six weeks.

CONCLUSION

Limonium peregrinum can be efficiently propagated by cuttings using a very free-draining medium and standard propagation facilities. *L. peregrinum* was successfully micropropagated once bacteria-free plant material was obtained.

NUTRITION OF CONTAINER-GROWN REWA-REWA (*Knightia excelsa*)

M. B. THOMAS AND M. I. SPURWAY

Department of Horticulture, Landscape and Parks
Lincoln College, Canterbury

Abstract. The response of container-grown rewa-rewas (*Knightia excelsa*) to five levels of N, P, K and lime were studied. The plants responded strongly to added N with the largest and most green plants receiving 450 to 600g N/m^3 while foliage was chlorotic at very low N rates. Phosphorus stimulated foliage growth but there was a linear increase in foliar chlorosis due to iron deficiency. Highest foliar dry matter production occurred with no added lime and pH of 3.5 in the peat: perlite medium, which is typical of a calcifuge.

INTRODUCTION

The New Zealand honeysuckle or rewa-rewa (*Knightia excelsa*) is a native tree which is found in lowland to lower mountain forests in New Zealand (3). It is found throughout the North Isand and the South Island in the Marlborough Sounds and on D'Urville Island. It belongs to the Proteaceae, along with *Persoonia toru*, the only other New Zealand native in this family. Metcalf (3) states that it will grow in almost any well-drained, friable soil and can tolerate dry situations.

Macadamia integrifolia is also in the Proteaceae and has foliar similarities such as the spiky evergreen lanceolate leaves. Macadamias were shown to have particular nutritional requirements (6) and it was decided to evaluate the nutrition of container-grown rewa-rewas with the objective of comparing these two plants with a view to make recommendations for potting mixes.

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Abstract. The response of container-grown rewa-rewas (*Knightia excelsa*) to five levels of N, P, K and lime were studied. The plants responded strongly to added N with the largest and most green plants receiving 450 to 600g N/m^3 while foliage was chlorotic at very low N rates. Phosphorus stimulated foliage growth but there was a linear increase in foliar chlorosis due to iron deficiency. Highest foliar dry matter production occurred with no added lime and pH of 3.5 in the peat: perlite medium, which is typical of a calcifuge.

INTRODUCTION

The New Zealand honeysuckle or rewa-rewa (*Knightia excelsa*) is a native tree which is found in lowland to lower mountain forests in New Zealand (3). It is found throughout the North Isand and the South Island in the Marlborough Sounds and on D'Urville Island. It belongs to the Proteaceae, along with *Persoonia toru*, the only other New Zealand native in this family. Metcalf (3) states that it will grow in almost any well-drained, friable soil and can tolerate dry situations.

Macadamia integrifolia is also in the Proteaceae and has foliar similarities such as the spiky evergreen lanceolate leaves. Macadamias were shown to have particular nutritional requirements (6) and it was decided to evaluate the nutrition of container-grown rewa-rewas with the objective of comparing these two plants with a view to make recommendations for potting mixes.

MATERIALS AND METHODS

Experimental Design. A four-factor response surface programme of the central composite design with incomplete blocks was used as for similar work (5). It involved N, P, K, and lime additions with 30 treatments arranged in 10 blocks each consisting of three sub-blocks and four replicates per treatment.

Fertilizer Rates and Potting media. The fertilizer sources used in the experiment for N, P, and K were Osmocote (26%N), superphosphate (8%P) and sulphate of potash (39%K), respectively. Lime was applied as a mixture of dolomite and agricultural lime (3:1). In addition, trace elements were applied in the form of "Sporumix A" at 150 g/m^3 and Fetrilon iron chelate at 360 g/m^3. All the fertilizers were mixed as a basal dressing in the potting mix, although N and P were given as two equal applications with half being applied initially and the other half 7½ months later as a top-dressing (lightly worked into the surface).

The medium used was equal parts (1:1, vv) Hauraki sphagnum peat and fine grade perlite. Containers used were PB 8 (4.8 l) polythene Planterbags.

Plant Material. One-year-old tube-grown seedlings were potted-up on 1 July, 1981. The plants were about 90 mm tall at potting.

Growth Environment. The experiment was carried out in a thermostatically controlled glasshouse with a minimum temperature of 8°C. The glasshouse was equipped with automatic fan ventilation, with fans operating when the temperature exceeded 21°C, that maintained the maximum temperature at approximately 5°C above ambient temperature. Supplementary lighting with 100 watt incandescent lamps 2m above floor level at 1.5m centres was given to increase photoperiod to 16 hours. The seedlings were watered by hand when necessary.

Data Collection. Media samples were taken at harvest time from 8cm deep cores and were analysed by Analytical Services Limited, Cambridge, New Zealand, with the methods described by Thomas (5). Chlorosis ratings were obtained at harvest using a visual rating system where plants were scored from 0 for severe chlorosis or defoliation, to 5 for normal healthy green leaves.

Plant tops were harvested at 12 months and oven dried. Foliage samples were taken randomly using the first two fully enlarged or mature leaves on the top of the plant. Samples were aggregated together and sent to Analytical Services Ltd, who used Kjeldahl digestion for N, and nitric-perchloric acid digestion for other nutrients.

Data from this experiment were statistically analysed for analysis of variance and F test. Data presented in graphic form in this paper were computed from the equations of the response surfaces.

RESULTS

This experiment, firstly, demonstrated the dominant and important role of nitrogen for the growth of container-grown plants. Plants showed deficiency symptoms and poor growth at low N rates (Figure 1) but responded strongly to increasing levels of N which were supplied as a basal and sidedress application after seven-and-a-half months (as were P rates).

The largest and most green plants (Figure 2) were obtained at 450 and 600g N/m^3. The latter rate still left significant nitrate levels in the mix at harvest time (Table 1) while leaf N appeared to relate well to the difference in media levels with the maximum rising to 1.5%N (Table 2). Severe chlorosis occurred at the nil and 150g rates of N/m^3 (Figure 2) while higher rates produced larger and greener plants.

Phosphorus additions also had a strong influence on both growth and plant quality. Optimum dry matter production was over the middle rates of added P and declined strongly with nil or 400g P/m^3 (Figure 1), even though this nutrient was applied in two applications. The more important factor was the influence of P on the appearance of the plants since there was a linear decline in quality (increasing chlorosis) with each additional rate of added P (Figure 2). The application rate of 300g P/m^3 resulted in 0.38% foliar P which was three times higher than with the 100g P/m^3 rate while foliar iron appeared higher with the latter treatment (Table 2). In general the best quality plants were those with nil P, high N and also high K; however, there was no significant response in foliar dry weight to added K.

Highest dry matter production was with nil lime and a pH of 3.5 in the peat:perlite media. Growth was significantly poorer with any lime additions and where the pH was in excess of about 5.5 (Table 1).

Table 1. Potting mix nutrient levels and pH.

Added nutrients (g/m^3) and lime (kg/m^3)			Potting mix nutrients (mg/l)						
N	P	K	lime	Nitrate-N	P	K	Ca	Mg	pH
0	200	166	6	2					5.92
600	200	166	6	78					5.19
300	0	166	6		3				6.65
300	400	166	6		56				5.20
300	200	0	6			1			5.41
300	200	332	6			25			5.81
300	200	166	0						3.47
300	200	166	12						6.08
150	100	83	3	12	14	4	119	36	6.07
300	200	166	6	35	35	6	202	47	5.78
450	300	250	9	68	28	10	191	52	5.85

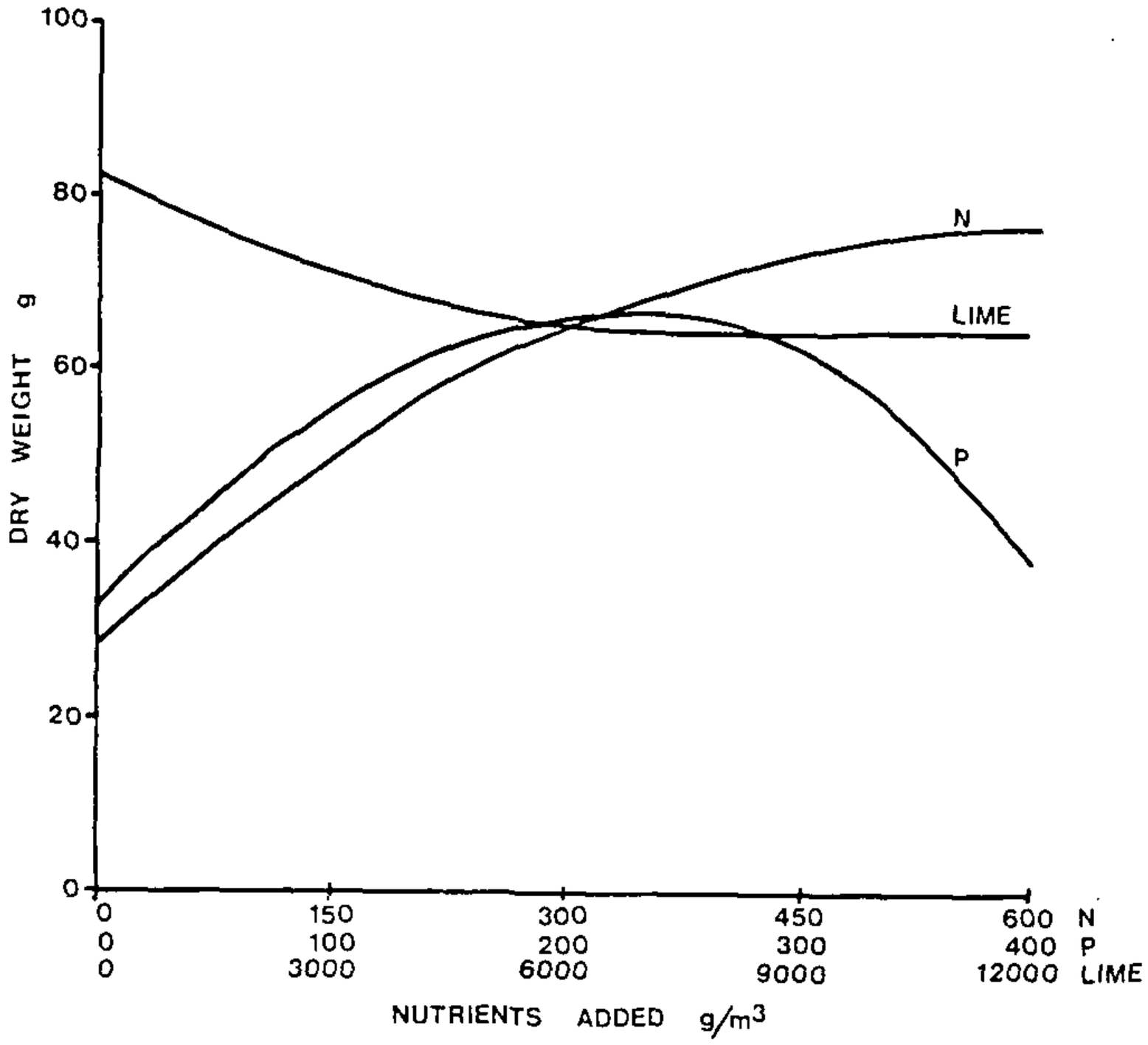

Figure 1. The influence of N and P fertilization and liming on foliar dry matter.

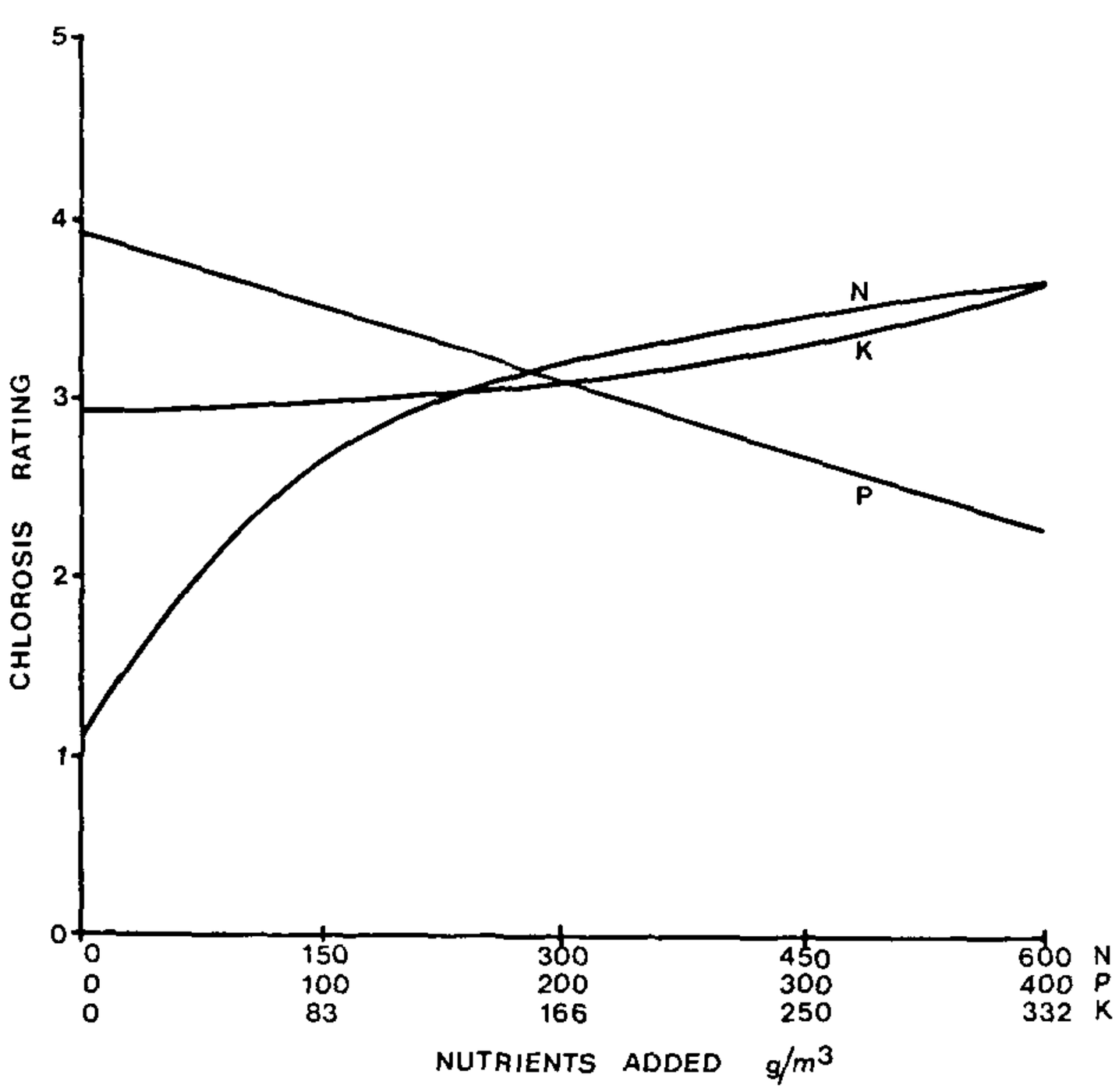

Figure 2. The influence of N, P and K fertilization on foliage colour ratings (severe chlorosis = 0 to 5 = green and full health).

Table 2. Leaf nutrient levels.

Added nutrients (g/m³) and lime (kg/m³)				Leaf nutrients (%)					
N	P	K	lime	N	P	K	Ca	Mg	Fe (ppm)
0	200	166	6	1.10					
600	200	166	6	1.50					
300	0	166	6		0.06				
300	400	166	6		0.26				
300	200	0	6			0.35			14
300	200	332	6			1.40			
300	200	166	0				0.8	0.19	19
300	200	166	12				0.77	0.22	6
150	100	83	3	1.16	0.13	0.81	0.89	0.27	16
300	200	166	6	1.46	0.17	0.87	0.82	0.25	14
450	300	250	9	1.19	0.38	1.02	0.86	0.20	10

DISCUSSION

In 1974 initial work was reported-on, which demonstrated that nitrogen was a common and major factor for satisfactory container production of plants, including the Proteaceae (4). This work also demonstrated a dominant role for nitrogen which agrees with the work reported here; even though *Knightia* is in the Proteaceae, there was no indication that the N rates used were too high. However, *Knightia* growth was unsatisfactory at very low N levels. *Knightia* appeared more responsive than the proteaceous shrub, *Hakea laurina*, which showed depressed growth at similarly high N levels (7).

Unpublished work with *Macadamia integrifolia* (native of Queensland, Australia) used the same experimental design as the one reported here and indicates that *Knightia* has much in common with this species of *Macadamia*. These plants have several features in common. They have similar foliage, readily suffer from foliar chlorosis, respond similarly to fertilizers and belong to the same subfamily (Grevilleoideae) of the Proteaceae (1). Excessive P fertilization in macadamias caused foliar chlorosis yet, in common with *Knightia*, there was improved foliar growth at low rates (6). Foliar chlorosis in *Knightia* was probably triggered by unfavorable foliar P to Fe ratios, as was noted for *Macadamia integrifolia* (6). Table 2 indicates quite widely varying levels of foliar P and Fe but there was insufficient data to show trends.

In conclusion, the results indicate that plants can be grown with standard rates of slow release fertilizers but that mixes should not have superphosphate or lime added. Addition of iron, such as chelated formulations, and excellent drainage but good watering, will help minimise deficiency and ensure good plant quality with no foliar chlorosis.

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A SYSTEM FOR THE EVALUATION OF *ZANTEDESCHIA* (CALLA LILIES)

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Department of Horticulture and Plant Health
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The breeding and selection of summer flowering Zantedeschia hybrids has had a long history in New Zealand. Over the past 50 years amateur breeders have crossed and back-crossed selections originating from the following species: *Z. elliottiana; Z. rehmannii; Z. albomaculata; Z. tropicalis;* and *Z. pentlandii*. The result of this work has led to a wide spectrum of beautifully coloured hybrids suitable for cut flowers, potted plants or garden plants.

In recent years commercial nurseries have been able to exploit the tremendous potential of this crop through the rapid multiplication process of tissue culture. Previous to this technique, clones could only be multiplied by division which was very slow and often led to disease. With tissue culture propagation it is now possible to bulk up thousands of progeny from a single clone in a very short period of time. This process is, however, expensive and a clone must be thoroughly assessed before it is selected for bulking up.

Although companies involved in commercial rhizome production each have their own field plots for evaluation, a need has arisen to carry out comparative assessments of selections, from the various producers, at one common site. This need is being fulfilled at the Massey University Bedding Plant Trial Garden in Palmerston North, New Zealand.

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A collection of newly released cultivars has been established so trials can be conducted on a continuing basis. The evaluations provide accurate, unbiased information on cultivars submitted for assessment. To ensure impartiality, a three person assessment panel is used to collect the relevant data. The panel is comprised of Dr. D. Cohen, Plant Physiology Division, D.S.I.R., A. Jamieson, Ornamentals Advisory Officer, M.A.F., and T. E. Welsh. Tutor in Nursery Crops, Massey University.

EVALUATIONS

Timing. All entries are planted on the same day in early spring. Recordings are made at the time flowering starts and flowering finishes for each cultivar. This time period is expressed in weeks. Separate recordings are made on the life of individual blooms and are part for flower life (re-greening).

Habit. Average height and width of plants is measured when plants are at their peak flowering performance, usually 2 to 3 weeks after first flowers open. A descriptive rating is given to express the Branching Effect of each cultivar. A scale of 1 to 5 is used with 5 being the most heavily branched.

Description of Flowers. Size, shape, and colour are the parameters used to describe the flowers. Zantedeschia blooms are actually compound structures composed of a scape (expanded stem), a spathe (modified leaf), and a spadix (flower inflorescence).

Average *size* in centimetres is given for the scape from ground level and the length of the spathe is recorded. A measurement is also taken across the top of the spathe giving the longest and shortest diameters. This measurement is helpful in determining the shape of the bloom as observed from above.

Shape. Descriptive terms are used to visualize the top of the spathe. Using the ratio between the top measurements the following terminology is used:

Rounded = less than 0.5cm differential
Pointed = less than 1.0cm differential
Long Pointed = more than 2.0cm differential

Colour. Is difficult to express in exact terms, even using colour charts, because of the many pigments interacting within the spathe. While the yellows, creams and golds have a dominant base colour, the reds and deep purples have a dominant overlay colour. The beautiful pink, apricot, and bronze bi-colours assume a woodgrain effect as pigments change with age or growing conditions. To complicate matters, some cultivars have a light to deep purple blotch in the throat around the spadix. Also, most cultivars are green prior to opening and re-green as they become senescent. As many as four pigments can be expressed in varying shades within one bloom. Colour may also vary on different blooms from the same plant.

Therefore, a loose description is given for the overlay and base colours along with mention of the absence or presence of a purple blotch. Descriptive ratings are used to express the degree of "*Colour Change*" amongst open blooms within a block of the same cultivar. A 1 to 5 scale is used with 5 having the most dramatic degree of colour change. This rating should be regarded as a characteristic and not necessarily an attribute or fault.

Description of Foliage. The main parameters are leaf shape and colour pattern. No attempt was made to measure individual leaves as size is extremely variable. Shape can also be variable due to the physiological age of the growing point from which they emerge.

Leaf Shape. This is described by a diagram of numbered shapes ranging from lance, semi-spear, spear, semi-arrow, and arrow. Adult leaves arising from flowering growing points are used for leaf description.

Pattern. Leaves can be maculate (spotted) or immaculate (non spotted)—and variations between. This spotting pattern on the leaf blade is described by the following self-explanatory terminology: no pattern, slight pattern, medium pattern, and heavy pattern.

Quantitative Ratings. These are made to express the life of the bloom on the plant and the average number of blooms per plant.

Flower Life. As previously mentioned, blooms often re-green when they begin to close after pollen shed. This time period for senescence can vary from one to five weeks. To quantify this occurrence a rating scale of 1 to 5 is used. Sample blooms are tagged as blooms are fully open. They are checked daily. When no green on the outer spathe is apparent the tag receives one dot, at 25% two dots, at 50% three dots, at 75% four dots and at 100% the blooms are fully closed, receiving five dots. At this stage they are cut off the plant and recorded. A rating of 2 was given if complete greening occurred after three days and each point of the scale increases at 3-day intervals to a total of 15 days, which rates a 5.

Floriferousness. This attribute of a cultivar is also given as a quantitative rating. As blooms are completely closed and green they are cut off the plant and recorded. This dead heading takes place weekly. Cultivars averaging 0.5 blooms per plant received a 1, and up to 5 blooms per plant received a 5. Steps between 1 to 5 on the scale are based on average numbers per plant. This rating is affected by the correlation between rhizome size and flower number. Therefore, rhizome size is recorded with these results.

Comments. These are made on a result sheet to record any other observations. They may include pest or disease problems, certain flower abnormalities, or physiological characteristics.

CONCLUSION

The recording system used endeavours to determine a cul-

tivar's suitability as a cut flower crop, a potted crop, or as a garden plant. Those cultivars that are naturally compact and heavily branched should make good potted plants while characteristics such as stem length and flower life are important for cut flower crops. Cultivars which are very free flowering but have a short flower life could be well suited as garden plants.

These evaluations should assist breeders with their work as well as providing rhizome producers with the necessary information to pass on to their customers, all of which will help contribute to the success of *Zantedeschia*, "the flower with a future".

CAPILLARY BEDS—AN EARLY ASSESSMENT

ESME J. DEAN

Omahanui Native Plants
Oropi Road
R.D.3, Tauranga

Capillary beds were installed at Omahanui Native Plants in December, 1985. Although 9 months is a relatively short period of time to offer an assessment, I feel that current interest in capillary beds is high and our experiences to date could be of relevance.

I intend to outline structure, cost, management techniques, and offer an overall assessment of this system 9 months on.

Basically, capillary beds are a watering system where water is made available at the base of the container-grown plant rather than by an overhead sprinkler system. Water availability is an extremely important factor affecting plant growth rates and general plant health. Overhead watering inevitably has variable distribution, resulting in some overly wet and other very dry areas in the nursery. There is also considerable water wastage with fall on standing out areas and pathways. In the capillary system water is available at all times through capillary action from the moist sand of the bed up through the drainage holes of the container into the mix, providing the plant with moisture at all times. The results of constant water supply are to be seen in healthier, faster growing plants.

The decision to build capillary beds at our nursery was made when one standing out area desperately needed resurfacing. After reading an article in Aglink and hearing about capillary beds at a

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The decision to build capillary beds at our nursery was made when one standing out area desperately needed resurfacing. After reading an article in Aglink and hearing about capillary beds at a

seminar, we thought we would try this system rather than repeat the weed mat and overhead sprinkler layout of the rest of the nursery. We were applying for a Rural Bank development loan at that time and so included the capillary bed costs in the development schedule. The money was approved and work went ahead in November, 1985. We aimed to use the beds primarily for growing larger grade plants.

STRUCTURE

We constructed 682.5 square metres of capillary beds at a cost, including labour, of $9.63 per square metre. This does not include the solenoid valves and the automatic watering system already in existence. A drained-bed concept was used, as outlined in the New Zealand Nursery Research Centre Extension Bulletin No. 4. Briefly, construction was as follows:

1). The beds, each 3.25 metres wide, were constructed of 100 × 25mm timber on levelled ground. The timber framing was level across the bed.

2). Pumice fill was compacted inside this framing to form a slope from one side to the other of 1 in 80. The careful preparation of this layer is vital to the successful functioning of the bed.

3). Over the compacted pumice, black polythene of 125 microns was laid. At the lower end of the slope the polythene ends against the framing, whilst at the higher end it is taken up the frame and fastened to the timber edge.

4). The final layer, termed the capillary substrate, consists of approximately 3cm of graded sand. This is screeded to make a smoothed surfaces.

5). Water supply is through 16mm thin wall alkathene with micro tubes every 50cm. The feeder pipe runs along the higher edge of the bed so the water movement is down the slope and excess drains out the lower edge.

6). Adjoining beds were sloped so that they both drain into the same Novaflo pipe running underneath a metalled walkway.

7). An overhead watering system was also installed as a backup and to flush any salts accumulating on the mix surface. Although in Oropi's high rainfall (200mm a year) we do not envisage this being a problem.

On these beds we can stand approximately 10,000 plants in PB 8's or 8,000 in PB 12's.

ADVANTAGES OF THE CAPILLARY BED SYSTEM

1). **Growth.** Plant growth on capillary beds is said to be both faster and more even. Our observations and simple comparisons substantiate this. Early last January the first plants went onto the beds. Several species were selected for comparisons. The bulk of these plants were stood out on the capillary beds, whilst 10 of each

species were put onto weed mat with overhead watering. After 4 and 11 weeks very basic height comparisons were made. *Hoheria populnea, Alectryon excelsus, Pittosporum tenuifolium* and *Sophora microphylla* had all made considerably better growth (up to 30cm more) on the capillary beds. *Entelia arborescens, Corynocarpus laevigatus, Clianthus puniceus* and *Melicope ternata* were larger but not dramatically so. There was not much growth difference in *Beilschmiedia taraire* and *Schefflera digitata*.

Although these comparisons were not done very scientifically, we were and are pleased with the growth performance of most plants on the capillary beds.

Pittosporums put onto the beds at 50 to 60cm in early January were ready for selling at the end of March at 1 metre plus and with bushy growth. Better growth of such species means that more crops can be grown in a given area over a year thereby increasing nursery turnover.

2). **Phytophthora Control.** Latest theories on *Phytophthora* infection indicate that this fungus becomes a problem only when plants are under stress for various reasons. Probably the greatest cause of stress is an inadequate and erratic water supply. Capillary beds with their constant supply of water reduce stress on plants and consequently lessen their susceptibility to *Phytophthora* attack.

Earlier this year we moved older plants which were '*Phytophthora* prone' onto the capillary beds but they continued to die. Species which we have difficulty with are now going straight onto the beds as.soon as they are potted and, hopefully, we will see fewer losses this season.

Quintinia acutifolia plants have been on the beds since early April and are still healthy and growing well, whereas we generally have high losses of these plants at an early stage. So we are optimistic that such species will be grown successfully on a capillary system.

MANAGEMENT

Watering. Initially we only partially flooded the beds allowing approximately 40 minutes of watering, but found that the plants on the lower side of the beds were not receiving enough water. We now completely flood the substrate which takes 60 minutes. In summer two 60-minute waterings are allowed—mid-morning and late afternoon. Watering is controlled by a Richdel automatic watering system. Length and number of waterings obviously depends on weather, width of beds, size of plants, and the amount of water being delivered through the feeder tubes.

Plants are watered before being put onto the beds after potting so the dry mix will not spill onto the sand. A second thorough soaking once in place is important to establish water contact with the substrate so capillary action can begin.

Weeds. A constantly moist medium provides a very good environment for weed growth so that an efficient weed management programme is important. *Foresite*® is sprayed on the mix surface to prevent weed growth in the containers; keeping the immediate surroundings weed-free will, of course, cut down the number of weed seeds finding their way onto the beds. For seeds that do germinate, a routine handweeding at regular intervals and a thorough clean up between crops has meant that weeds have not become a problem for us. An experimental spraying of part of one bed with a strong *Foresite*® spray has controlled bittercress growth but not pearlwort or chickweed. We will continue to use such sprays as bittercress is difficult to keep under control with only handweeding.

Sand Replacement. At least 2.5cm of substrate—sand—is necessary to retain sufficient moisture for plant use. We found that we had to "top up" the sand layer significantly before the second crop went onto the beds. It would seem that this was due largely to sand consolidation and perhaps initial uneven distribution of the sand over the beds. However, there will always be some loss on plant roots and, because of scouring, in a few places where the polythene had not been laid close enough to the timber edging. It seems sensible to have a stockpile of sand for such replacement.

Wooden screeds extending across the framing to the correct depth make it easy to achieve the correct sand thickness. This process can be routinely carried out during the clean up between crops.

Shelter. Beds must be well sheltered to prevent or minimise the toppling over of plants by the wind. Plants which fall over dry out since the capillary action is interrupted.

Surface Maintenance. The surface of the beds needs to be smoothed flat (by screeding) before plants are stood onto the sand so that maximum contact is made with the drainage holes in the container base. Hollows in the sand may mean several holes may not have contact with the substrate and so the amount of capillary action is reduced. For the same reasons, planter bags must be seated flat on the sand.

When standing out plants we use strips of plywood laid over the sand to walk on. This stops the surface being disturbed too much before the plants are put down.

Micro-Tube Check. Regular checks need to be made of microtubes to ensure they are clear of sand particles.

CONCLUSIONS

The cost of setting up a capillary watering system is relatively high but, to offset the higher capital investment, there are the advantages of quicker plant growth and consequently higher

turnover of stock, plus superior plant health and quality.

However, to obtain a maximum return from the capillary bed, care must be taken:

1) To keep the beds well stocked throughout the year.
2) To establish management routines such as those outlined to ensure the most efficient functioning of the capillary system.

Over 9 months we have established routines necessary in management of capillary beds and our observations of plant growth and health have justified our decision to try this system.

EFFECT OF SOWING TIME ON PEACH ROOTSTOCK ESTABLISHMENT

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Abstract. The effects of four different seed sowing times, plus fungicide treatment, were evaluated for peach rootstocks direct-sown using seed from 'Golden Queen' peach. The two earliest sowings resulted in significantly higher seedling emergence and percentage buddable stocks, than later sowings. The second sowing time of May (late autumn) gave the highest seedling emergence (59.1%) giving 48.9% buddable stocks based on the number sown. Soil temperature and moisture were considered key factors influencing subsequent seed stratification, while prior handling and storage were also thought to influence the results. Fungicide treatment with thiram had no significant influence.

INTRODUCTION

The predominant method of propagating peaches is by T-budding of selected cultivars onto seedling peach stock. The choice of seed source, is not usually governed by any particular cultural value, but rather by ready availability of seed from the canning industry. Thus in New Zealand seedlings of the late maturing canning cultivar, 'Golden Queen', is the principal rootstock used for peach.

As with many temperate zone plants, peach seed requires a stratification period to promote germination. The conditions and length of the stratification period for peach is cultivar-variable (3, 4, 9) though from the literature 80 to 150 days at 4 to 10°C in a moist medium is usual (1, 3, 10, 12, 13).

The problems associated with peach propagation from seed vary according to climatic conditions. In warm temperate and subtropical regions the principal problem is the attaining of sufficient

turnover of stock, plus superior plant health and quality.

However, to obtain a maximum return from the capillary bed, care must be taken:

1) To keep the beds well stocked throughout the year.
2) To establish management routines such as those outlined to ensure the most efficient functioning of the capillary system.

Over 9 months we have established routines necessary in management of capillary beds and our observations of plant growth and health have justified our decision to try this system.

EFFECT OF SOWING TIME ON PEACH ROOTSTOCK ESTABLISHMENT

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Abstract. The effects of four different seed sowing times, plus fungicide treatment, were evaluated for peach rootstocks direct-sown using seed from 'Golden Queen' peach. The two earliest sowings resulted in significantly higher seedling emergence and percentage buddable stocks, than later sowings. The second sowing time of May (late autumn) gave the highest seedling emergence (59.1%) giving 48.9% buddable stocks based on the number sown. Soil temperature and moisture were considered key factors influencing subsequent seed stratification, while prior handling and storage were also thought to influence the results. Fungicide treatment with thiram had no significant influence.

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The problems associated with peach propagation from seed vary according to climatic conditions. In warm temperate and subtropical regions the principal problem is the attaining of sufficient

chilling to satisfy the stratification requirement (3). Once germination is achieved, seedling growth is such that stocks can be summer-budded and a satisfactory tree achieved within one year (7, 8, 13). However in cool temperate regions, attaining sufficient growth in the seedling to allow budding in late summer is more inclined to be a problem than provision of adequate winter chilling. Tree production under this system takes two years.

Management of the seedling under cool-temperate conditions is very critical. In New Zealand the traditional practice is to stratify in sand or sawdust and transplant the seedlings as they emerge. This has the advantage of allowing adequate spacing and uniformity of seedling age within rows.

In Canterbury, warm north-westerly winds in spring are common and these can severely check newly transplanted seedlings resulting in delayed budding. In response to this, some smaller nurseries in the Canterbury area have adopted a system of direct sowing. This method overcomes transplant problems and the associated costs of planting-out although it does involve thinning to ensure adequate spacing and results in variability in seedling size.

This paper reports on an experiment set up to investigate the effect of sowing time on seedling emergence and attainment of sufficient growth to allow budding at the optimum time under a direct sowing plus autumn budding system. A further objective was to evaluate the effect of seed treatment with the fungicide, thiram, at the different times.

MATERIALS AND METHODS

This experiment was located in Canterbury, New Zealand and was conducted over the 1984/85 season. The experiment was laid down within a 0.6 ha sheltered block on a Waikanui silt loam which had been in pasture for several years previously.

Seed from *Prunus persica* 'Golden Queen' were obtained from a cannery in the Hawkes Bay district. Prior to shipment the seed was dried in the open. On arrival the seed was stored in a cool locality indoors until sowing. Seed for fungicide treatment was dusted with a wettable powder formulation of thiram just prior to sowing.

Seed was hand-sown at four times: 26 April, 31 May, 5 July, and 5 August. This provided a separation of about five weeks between sowings.

Management of the trial followed the practice of the adjacent commercial block. Weed control was achieved by pre-emergence application of oryzalin (3.5 kg/ha a.i.) and simazine (0.75 l/ha a.i.) followed by spot spraying as required with paraquat/diquat mixture. There was no visible symptoms of toxicity from these chemicals. Peaches are sensitive to herbicides but are tolerant of oryzalin, and simazine at a very low rate (2, 5, 11).

The spray program for pest and disease control included regular applications of captafol and streptomycin with pirimicarb added when required for aphid control. Trickle irrigation was used when required.

The experiment was a randomised block design with five replicates and eight treatments. Each was sown with 100 seeds and seedling emergence was monitored regularly during the growing season, with the final assessment on 25 February, 1985. At this time seedling girth was measured with vernier calipers.

RESULTS

Seed treatment with fungicides prior to sowing had no significant influence on seedling emergence and this data is not shown.

Soil temperatures and progressive seedling emergence at the four different sowing times are shown in Figure 1. Early sowing resulted in a higher total percentage emergence and this was strongly reflected in the overall percentage of plants that were evaluated as being sufficient size for budding (Table 1). Emergence was particularly high for the second or May sowing while the two earliest sowings had significantly higher percentages than the later ones. April and May sowings yielded greater than 80% buddable plants which dropped to 65% for July and only 20% for August, of the number that emerged.

Figure 2 depicts emergence and suitability for budding as a percentage of the number sown rather than those that had emerged. This presents a more sober view of the yield of buddable plants related to the initial number sown. In the most successful sowing, 49% of the seed developed into buddable plants; it was similar for April but only 30% and 8% of adequate girth resulted from the two subsequent sowings.

Table 1. The influence of sowing time on emergence of peach seedlings and percent buddable stocks of those that emerged.

Date	Mean Percentage Emergence	Percentage of seedlings buddable
26 April	50.3	88.7
31 May	59.1	82.2
5 July	41.0	64.9
5 August	39.2	19.8
LSD (5%)	6.5	8.8
Significance levels:		
linear	p < .001 (**)	p < .001 (**)
quadratic	p < .001 (**)	p < .001 (**)
cubic	p = .017 (*)	p = .225 (NS)

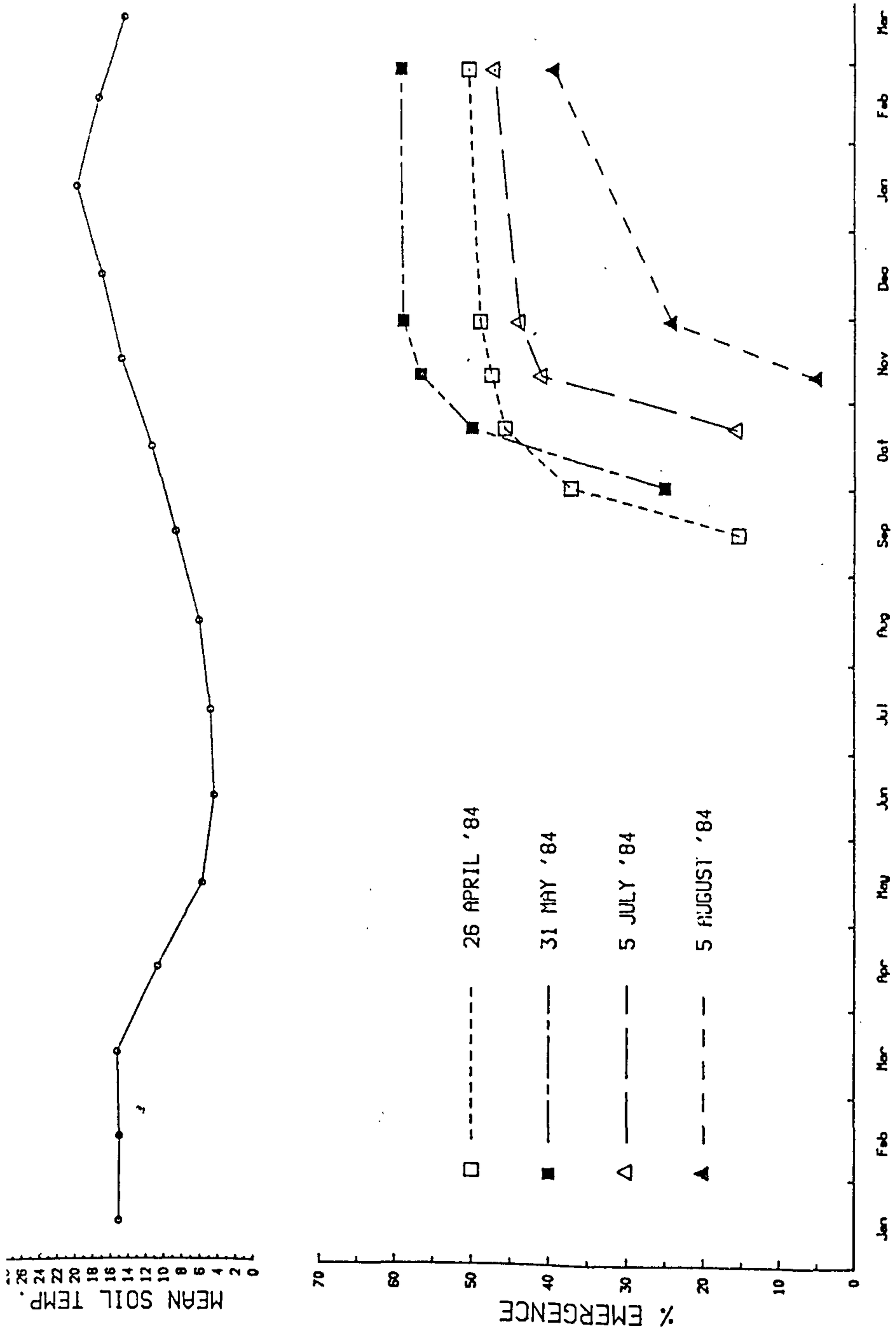

Figure 1. Soil temperatures and seedling emergence resulting from four different sowing times.

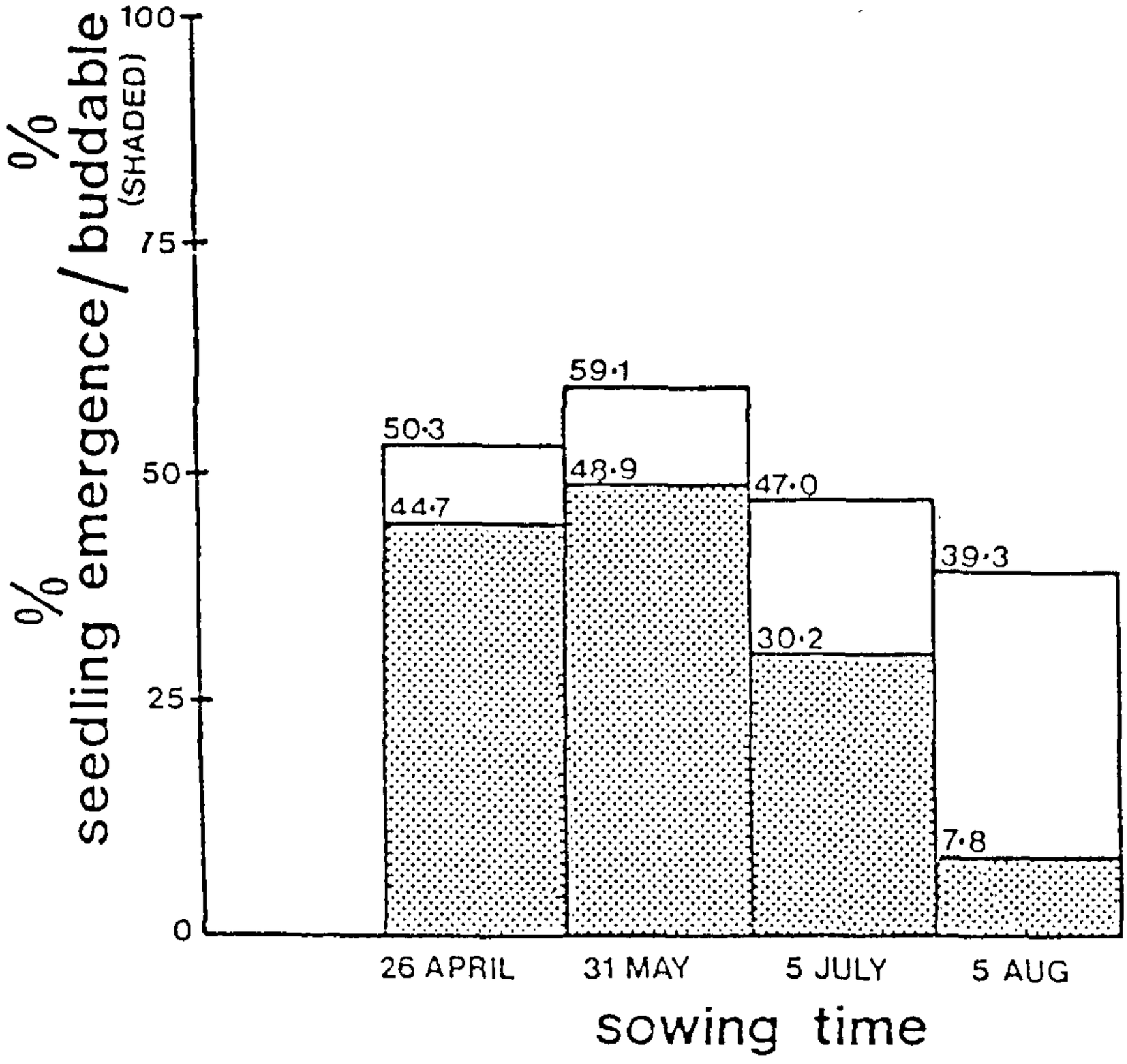

Figure 2. *Seedling emergence and suitability for budding as a percentage of the* number sown.

DISCUSSION

Early sowing resulted in a higher seedling emergence, earlier emergence and in a greater proportion of emerged seedlings being buddable by late February. These effects of early sowing time can be attributed to provision of adequate exposure to stratification conditions. Late sowing can result in a very low proportion of buddable stocks (Figure 2).

The higher emergence observed for the May sowing compared to the sowing in April was unexpected but may be due to overexposure to low temperature or induction of secondary dormancy in those sown in April. Guerriero and Scalabrelli (6) observed both phenomenon in a comparison of the effect of duration of stratification on seed of a number of peach rootstocks.

Even for the early sowings percentage emergence was not high (i.e. maximum of 59.1%). This may in part be due to the handling and storage of the seed prior to sowing. Briggs (3) observed a rapid decline in viability when seed was stored at 25°C, while at 6°C seed remained viable for a number of years. Briggs (3) and Harris (7)

report a considerable improvement in percent emergence with drying under cool conditions, rather than outdoors in direct sunlight.

The key environmental parameters for successful stratification are soil temperature and moisture. As these can vary considerably among seasons and districts it is not possible to pinpoint the optimum sowing time in advance. However, these results demonstrate that in cool-temperate regions early sowing is essential for achieving sufficient seedling emergence and growth.

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PROPAGATION OF *DESMOSCHOENUS SPIRALIS* (PINGAO) FROM SEED

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Pingao, *Desmoschoenus spiralis,* is a native plant endemic to New Zealand. It is a sedge and its natural habitat is the sand dunes. The thick rope like stems and long roots allow it to thrive in the shifting sands. The stiff leaves, which range in colour through green to gold to orange, form semi-tussocks.

In pre-European times pingao was a common plant in both the North and South Islands of New Zealand. Now, farm stock and feral animals graze the foreshore and introduced plants, marram grass, buffalo grass and lupins, which have been widely used to control the spread of the sand dunes, have displaced this native plant. Pingao is localised and may become endangered.

Pingao has always been used for a weaving material by the Maori people, for kete, and for tukutuku panelling which lines the walls of the meeting houses. In the last decade, the renaissance of taha Maori, both in the weaving arts, and the refurbishing of marae, have increased the use of the pingao fibre, and in many areas local supplies are insufficient. There has been great interest in the cultivation of pingao to renew this resource.

PROPAGATION BY LAYERING

Layering, the covering of a stem runner with sand until the roots form, is a slow method.

PROPAGATION BY TIP CUTTINGS

Tip cuttings of summer shoots, root within four weeks (1). But this method involves cutting into the diminishing stands of pingao. In coastline areas such as the east coast of the North Island the stands of pingao are so sparse that tip cutting is impractical for local propagation.

PROPAGATION BY SEED

Propagation of pingao by seed has the reputation of being difficult, with low germination rates (1, 2). Since the pingao plant flowers in September (early spring) in the Auckland area, seed heads were collected between mid-November and mid-December. They were dried for two weeks, the seed removed, and sown immediately. In 3 to 4 weeks the seedlings appeared, with an estimated germination rate of 80%. Seedling growth was slow and a weekly

dose of a dilute liquid fertiliser was applied, with regular use of a fungicide.

The seedlings were pricked out into 7cm propagation tubes, and later potted up in polythene bags (PB5). Table 1 and 2 show the media used.

Table 1. Bark and pumice sand mixtures for propagation of pingao from seed.

Composition of basic mixture	For seed germination	For seedling growth (7cm tube)	For growing on of seedlings (PB5)
Bark (No 1) potting mix	25%	25%	25%
Pumice sand	75	75	75
Fertiliser added per M^3 of basic mixture			
Dolomite lime	3 kg	5 kg	5 kg
Superphosphate	1 kg	1 kg	1 kg
Calcium ammonium nitrate	1 kg	1 kg	1 kg
Osmocote NPK 19:2.6:10		2.5 kg	5 kg
Trace elements			At standard rate

Table 2. Peat and pumice sand mixtures for propagation of pingao from seed (3)

Composition of basic mixture	For seed germination	For seedling growth (7cm tube)	For growing on of seedlings (PB5)
Peat	50%	50%	25%
Pumice sand	50	50	75
Fertiliser added per M^3 of basic mixture			
Dolomite lime	3 kg	3 kg	3 kg
Ground lime	1.5 kg	1.5 kg	1.5 kg
Superphosphate	0.75 kg	1 kg	1 kg
Potassium nitrate	0.4 kg		

Pingao seed gathered in November and December gave high germination results. Seed collected in February was found to be largely infertile (1). Viability tests on pingao seed, collected in April, using the tetrazolium test, have shown a potential for germination of 87% (2).

It seems possible that a dormancy mechanism is laid down in

the seed in the last stages of maturation. This may be avoided by the early collection of seed heads.

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PROPAGATION OF SOUTH AFRICAN PROTEACEAE BY SEED

JACK HARRE

R.D. 7, Feilding

Thirty years ago the germination of Proteaceae seeds and their survival through to a saleable plant was a great mystery to me and, judging by the results I sometimes see in New Zealand and other countries, it still is to many people.

In this paper I will outline the methods I have developed during those thirty years and now use to propagate this family of plants from seed in my particular climate. In doing so I must generalise as there is insufficient time to go into the finer details for each species and cultivar. In practice one should never generalise about proteas.

Proteas are unique in some of their demands for survival. A basic understanding of where, how, and why they grow in nature will help understand why they need these specific conditions.

Almost all the proteas we know in New Zealand gardens come from the Cape Province of South Africa and are mostly found in an area about 600 km long by 80 km wide, stretching from Capetown eastwards to Port Elizabeth along the coast and incorporating the mountain ranges that run parallel to the coast line. Rainfall is similar to New Zealand—750 to 2000 mm, (30 to 80 inches) with dry autumns. Although some kinds, mostly leucadendrons, and the more common proteas are found on the coastal plains, most grow in the mountains—from around 500 to 1000 m. Here they are exposed to constant air movement which is mostly gentle. They are often shrouded in cool afternoon mists, even right through the summer months and are growing in incredibly rocky ground which is usually steep and well drained. None of the plants are found growing on a north facing slope unless they are of the blue/grey leaf forms, such

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as *Protea amplexicaulis, P. laurifolia, P. eximia,* etc. and, although it can snow at these levels, it is rare for frost temperatures to drop below −2 or 3°C. The soil amongst the rocks usually has very low nutrient levels, especially phosphate; the pH is low, in some places as low as 3.0.

From this brief outline we can see that proteas are very selective where they grow and, in fact, almost nothing else will grow where they are found. They require good air movement, good drainage, low phosphate and pH levels, and light intensity below that occurring on a sunny north face. They will tolerate high rainfall provided it does not occur in the autumn and they do benefit greatly from cool afternoon mists dampening and cooling their leaves. As seedlings they will tolerate ground frosts of a short duration (two hours) at temperatures down to −3.5°C.

There is one great difference between the conditions where proteas are found in South Africa and the New Zealand climate and that is the temperature/humidity ratio. In South Africa when it rains it also gets cold, as the rain clouds come in from the southern oceans. In New Zealand when it rains, especially in the summer it often comes from the northern tropics and is accompanied by high humidity and temperatures. The 80/80 combination is quite common and this is our undoing as it induces fungal invasion in proteas both above and below the ground. It is a problem we must always be aware of, not only in the summer but also in the winter months when we can have warm day temperatures at humidity levels of 85% and over. Proteas do not tolerate hot, moist air.

How do we provide conditions that match those in which proteas will succeed?

Dealing with the environmental ones first, air movement and light control, my preference is to do all propagation out-of-doors but under a rain-proof roof. This is achieved by having a structure with benching 60 cm above ground level over which is a PVC roof, 1 to 1½ metres above the benching. This roof is sitting on runners so that it can be run back off the entire area to let the rain fall on the seed trays or full light on the seedlings. Alternatively it can be left in place to protect them from frosts, excessive rainfall and light levels. There are usually no sides on it but hessian is sometimes stretched around it as frost protection.

This structure provides the best possible air movement, regulates the light on a bright sunny day to around 6,000 f.c., which is the ideal light intensity, and allows to either expose the seedlings to rain and light, or protect them as necessary.

All the other needs of the protea plants are incorporated in the medium used for seed germination and for subsequent growing on. I only use soil-based media for any phase of protea propagation with never more than 10% peat in any mix.

Trials concluded last February, which were carried out over the

previous three years, show conclusively that proteacea plants are seriously affected in their ability to develop a satisfactory root system (in at least some New Zealand soil types) if the roots have been in contact with peat (at more than 10% of the volume of any medium) at any stage of development from initiation to final siting. Those that have been in contact with pinebark are even worse.

For the seed germination phase I use 50 parts turf loam, 20 parts coarse river sand, and 30 parts either perlite or coarse pumice. Alternatively, 50 parts turf loam and 50 parts Waikato grade 14 pumice sand (from Mercer) can be used.

If the seed is being sown toward mid-winter when slow germination and development is expected I replace 10 parts of the pumice with 10 parts of peat. This helps to stabilise the pH, which tends to rise with the water I have to use.

For sterilising I prefer heat at 185°F for 20 minutes. Failing this, methyl bromide is all right provided it is applied four to five weeks prior to use.

If using loam, pumice, or perlite of unknown phosphate and pH levels these should be checked before large scale seed sowing.

Seed trays should not be deeper than 5 cm (2 in.). The reason for this is that seedling proteas have very dominant tap roots in their initial stage of development and if sown in deep trays, they develop such a long and massive tap root before they are ready to pot up that severe damage can be done to them during handling. By keeping the depth to 5 cm it will force them to produce a more fibrous root system that is easier to handle. My preference is to use the Worsdale tray for all seed germination for reasons I will explain later.

Protea seed falls into two categories—that of the winged type and that of the hard-shelled forms. All the proteas that one is likely to come across in the nursery trade, except *P. magnifica*, as well as about half of the leucodendrons, have winged seeds. These are the types that are held captive in the seed heads until released by fire, which happens every 15 to 20 years in nature. Seeds of these are all easy to germinate, although viability does vary greatly from year to year in some cultivars. The hard-shelled seeds are found in the remainder of the leucodendrons, all the leucospermums, and most of the other genera: *Mimetes, Paranomus, Serruria,* etc. These seeds are shed each year, usually mid-summer to early autumn. They are often slow and erratic in germination, taking from 3 to 15 months to germinate.

There has been some work done in South Africa and by myself on breaking dormancy in these seeds. The treatments given in South Africa range from soaking in hydrogen peroxide and/or low doses of acid, soaking in sour milk for 3 weeks, pouring boiling water over them, grinding nicks in the shell, and even cracking the seeds with a hammer.

Gert Britts at the Protea Research Station in South Africa, has

completed a 24 month trial using one variant of *Leucospermum cordifolium*, sowing seed every 30 days during that period. His results clearly show that germination was greatly improved in the months when a sharp drop in temperatures was experienced within 30 days of seed sowing (as would occur in early winter), with poor results recorded on a rising temperature pattern. His findings are in line with the observations I have made on a number of cultivars covering several species. An extension to these observations is that these seeds seem to become more difficult to germinate as they age, probably because of dehydration after removal from the heads. I am of an opinion that very high germination rates could always be achieved with this type of seed if they were never allowed to become dehydrated between harvest and sowing. This problem can be alleviated to some degree by soaking them in water for 30 minutes at 60°C just prior to sowing but this will not totally compensate for dehydration as they appear to go into a state of dormancy. Stratification has been trialled on a number of occasions with inconsistent results, probably due to variable seed quality.

Because of the foregoing, my advice is to sow all proteaceae seed in the autumn on a falling temperature pattern. Some of the winged types give good germination with spring sowing but there can be a problem getting such juvenile plants through the high temperature and humidity periods of early summer.

For seed sowing, trays are filled to the rim with a medium that is of such a moisture content that it will just hold together in your hand if it is squeezed gently. This moisture content is important as it will not be watered again until germination has commenced. Firm down the medium in the tray but do not pound down hard, just firm. Put the seed into a container, and to every 200 seeds add 200 ml volume of dry coarse sand. To this add ¼ tsp. captan and mix it all well. Sow the seed not exceeding a density of one seed per sq.cm.—otherwise when they germinate the seedlings will push each other up into the air and some will dehydrate and die. Firm the seed down, but do not pound it, and top up the tray to overflow with medium, levelling it off by drawing a lath over the surface. Do not firm down this surface. Stack the finished trays one on top of the other, putting a barrier of weed mat or tray liner between them. Stack out of direct sunlight and strong drafts. Do not sheet down with plastic or any other material.

The stacked trays are left unattended for 17 days at temperatures 18°C and over, or 21 days below that temperature.

On the due date, unstack and place the trays in the germination area. Water very lightly and then immediately cover to a depth of 2 to 3 mm with sand into which, for every liter volume of sand, 2 mg of captan has been added.

If the moisture content is correct at sowing, as described earlier, seed of most of the winged cultivars will germinate from the

18th to 25th day at the higher temperature, and 25th to 35th day at the lower range. The hard-shelled types can be left stacked with safety until the 30th to 35th days then spread out and handled in the same way. Light levels are of great importance in the first 90 days following germination. It should be controlled to give an average level of approximately 6,000 f.c. It is not necessary to measure this light but it must be controlled so that the stems on the seedlings maintain a green/brown to green/red colour, depending on cultivar. If the colour of these stems becomes green/white and almost translucent, the light level is too low, but if the stem colour becomes dark brown to reddish light intensity is too high. The high incidence of fungal invasion in some operator's hands is a direct result of too low a light level, while the bright-coloured stems are a result of too much light at some stage. In cloudy weather seedlings should be exposed to full light. Under well controlled conditions development of the seedlings is rapid and most cultivars will be ready to pot up within four weeks from seed germination. I prefer to do this at the first true leaf stage. If they are left any longer most will develop long tap roots that will be damaged on further handling.

Maintenance from seed germination to potting consists of providing adequate air movement and proper light control. These are the most important ingredients to success. If these are well controlled most other problems will not appear.

Spraying with captan at 75% strength every 10 days should be done and on the 20th day after germination Alliete® at half strength should be applied. Watering should be prudently done, taking care not to overwater. The plants are better being a little too dry than too wet. Exposure to natural rain is highly beneficial and if possible should be used as the water source rather than tap water.

Contrary to general practice, I always water late in the day leaving the plants wet overnight, which is the same as they have in nature. If frosts are not a problem the seedlings may be exposed to dews each night which will practically eliminate the necessity to water during this phase. Nightly exposure to dews will also greatly reduce the incidence of fungal invasion. Frosts, unless below −3°C, are not a great danger on well-grown seedlings. I have had a range of cultivars frozen to −5°C for 3 hours without any losses. However, frosts of greater than −2.5°C at tray surface level may affect seeds that have started germination but not emerged. It is generally better to avoid temperatures below −2°C.

Seedlings that have not been well handled and are in soft condition through low light levels, or from being kept in high humidity conditions, such as closed-in glass or tunnel houses, will suffer damage at levels just below 0°C.

Seven days before the seedlings are to be potted up, apply captan at the standard rate as a drench. This will clean up any fungal problems that may be present.

The following day the plants should be "wrenched". This is carried out by poking your finger up through the mesh on the bottom of the trays and disturbing the liner. If solid based trays have been used wrenching may be done by using a table fork to disturb them. Either method will effectively disturb the long tap root of the seedling and cause the plant to produce a strong fibrous root mass over the next five to seven days. The trays of seedlings should not be watered at least until the day following the wrenching or even the second day, but to protect the plants from dehydration they should be kept in full shade and out of strong drafts for the period between wrenching and until they are again watered.

Withholding of water is important for two reasons. Firstly, watering immediately following wrenching can induce fungal problems in the root system which enters through the damaged tissue caused by the disturbance and, secondly, the plants' roots must be made to hunt a little for moisture and it is, therefore, necessary to keep them on the dry side. This wrenching will reduce losses at potting up to nil provided it and the potting phase are well done.

Potting up should be done before the plants get too big and especially before they get weak at ground level, which they will do if left too long in an undisturbed state in a gentle environment. It should be done as they are getting their first pair of true leaves.

The medium I use is ⅔ turf loam and ⅓ pumice sand or coarse river sand. This should be sterilised either by heat or gas as was the germination medium. Moisture content should be the same as for seed sowing. Terazole® may be incorporated at the standard 100 gms per cubic metre to give added protection from *Phytophthora*, especially when entering the warmer early summer months.

Container size for the cultivars common in the nursery trade is not critical and the 5 cm square liner is satisfactory. With some of the more difficult subjects the initial container size is critical as it is important that these cultivars rapidly get their roots to the perimeter and bottom of the pots. This is particularly so with those that are found in dry rocky ground in nature. These cultivars do not do well unless their roots are somewhat constricted and able to run along a hard surface. Under cultivation the sides of a tube acts as a substitute for rocks. If you look closely at the roots of these cultivars you will see that they have the ability to fasten themselves to a hard surface like ivy does on a wall and this enables them to get moisture from the condensation on the underside of the rocks. With these cultivars it will be found that the small 2.5 mm round propagation tube will give best results in the initial potting phase with a 50/50 mix of loam and pumice sand. (This is also true for the Western Australia banksias.)

When potting up, plants should be extracted from the trays gently, taking care to cause as little damage as possible to the roots. They should be set at a height in the liner a little lower than they

were in the tray and the liner should be filled to an over-full level. The medium must be left relatively loose in the liner, just firm enough to hold the plant upright. Proteas will only generate roots if there is oxygen in the soil. For this reason the medium should be left uncompacted and preferably not watered for at least three days following potting up. They should however be protected from conditions that will cause dehydration the same as following the wrenching phase. Three days following potting the plants may be watered sparingly and exposed to higher light levels and adequate air movement. They can be placed in an open environment provided they are protected from prolonged periods of high light intensity (7,000 f.c. and over), constant strong winds, and frosts below −2°C. It may be necessary also to protect them from excessive rainfall.

For this, or any other phase of production, I do not favour tunnel houses or glass houses because of the problems proteas experience with the high humidity created in these structures. Fungal problems can be induced into the plants under such conditions and, although it can be controlled by weekly drenchings of fungicides, it is only controlled but not cured and may be carried through to the later stages of the plants' development. This can be seen in the high casualty rates often experienced in the growing on phase in production nurseries and later in garden centres where maintenance spraying is not regular or carried out at all.

Once the seedlings have developed to the stage of potting up, hardened off, and producing a strong healthy root system, they can be grown on. However the operator should always bear in mind that proteas are like people. To stay healthy they need good air, the right amount of light for their particular species, not too much water, and a restricted diet.

GETTING STARTED IN MICROPROPAGATION OF TASMANIAN BLACKWOOD (*ACACIA MELANOXYLON*)

CATHY JONES

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Abstract. *Acacia melanoxylon* R.Br. plants have been regenerated from dissected embryos using tissue culture techniques. Shoots excised from seedlings grown *in-vitro* formed roots in a non-sterile environment following an *in-vitro* auxin/cytokinin treatment. The Quoirin-LePoivre (Q-LP) medium currently used for *in-vitro* culture is not optimal; addition of activated charcoal resulted in clones with less foliage abscission, larger shoots, more leaves, and higher leaflet numbers.

INTRODUCTION

Interest has been shown in Tasmanian blackwood (*A. melanoxylon*) as a plantation species as it grows reasonably fast and has an attractive, fine-grained timber suitable for furniture (1). Selection of clones with good stem form has not yet been undertaken in New Zealand, but clonal selection has been carried out in South Africa. Tissue culture techniques may provide early amplification of limited imported explant material.

Cutting propagation is not always successful with older material as rooting is often difficult. Micropropagation has worked with many species where cuttings have been unsuccessful and, although relatively expensive, can provide stock plants for further multiplication. With our present regulations, importation of cuttings and rooted stock involves lengthy delays for quarantine, because of the risk posed by insects and diseases carried on the foliage or in the roots and surrounding soil. Tissue culture may provide a better means of importing selected clones of *A. melanoxylon*. Disinfested micro-cuttings would guarantee insect-free material and greatly reduce the risk of introducing viral, bacterial, or fungal pathogens. On arrival in New Zealand, *in-vitro* material could be given rooting treatments and grown in a glasshouse environment to ensure that any stock released was free of pathogens, and also to aid the hardening-off of plant material. It could then be multiplied using conventional, less expensive, rooted cuttings.

Tissue culture of *Acacia* species has been reviewed by Skolman (2). Culture of *A. melanoxylon* is briefly described, and Bonner (2) is reported to have grown a root for more than a year in liquid culture. No plants were ever regenerated. Tissue culture of *Acacia koa* A. Gray is described more fully by Skolman (2), who reported that plants were regenerated from callus cultures derived from shoot tips. However the methods developed were very labour intensive and growth responses were slow.

Preliminary work with *A. melanoxylon* at the Forest Research

Institute, Rotorua, is described in this paper.

Seeds provide a ready source of sterile plant material. Plants grown *in-vitro* from these should provide useful leads for propagation of mature explant material. A potential application would be bulk vegetative "amplification" of limited amounts of seed from progeny-tested parent trees.

BASIC TECHNIQUES

Extraction of embryos from seeds. The seed used was from a parent stand at Jubilee Creek, South Africa. Seeds required scarification with a scalpel cut (Figure 1) before they could imbibe water and for the seed coat to become sufficiently soft to allow dissection of the embryos.

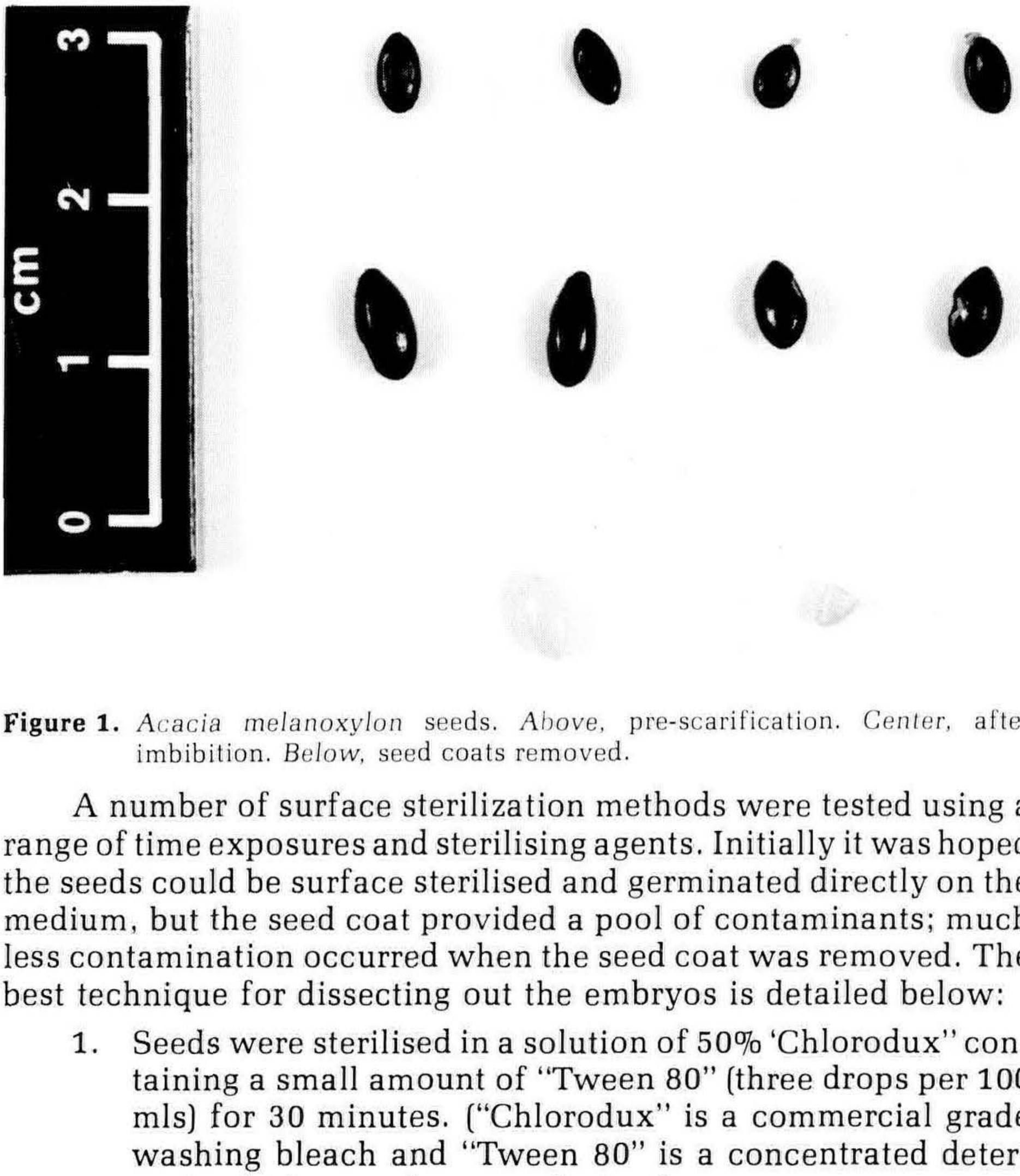

Figure 1. *Acacia melanoxylon* seeds. *Above*, pre-scarification. *Center*, after imbibition. *Below*, seed coats removed.

A number of surface sterilization methods were tested using a range of time exposures and sterilising agents. Initially it was hoped the seeds could be surface sterilised and germinated directly on the medium, but the seed coat provided a pool of contaminants; much less contamination occurred when the seed coat was removed. The best technique for dissecting out the embryos is detailed below:

1. Seeds were sterilised in a solution of 50% 'Chlorodux" containing a small amount of "Tween 80" (three drops per 100 mls) for 30 minutes. ("Chlorodux" is a commercial grade washing bleach and "Tween 80" is a concentrated detergent solution used as a surfactant).
2. The seeds were then rinsed in sterile water and, using

aseptic techniques, each seed coat was cut and the seed returned to sterile water for a further four hours imbibition.

3. The swollen seeds were soaked in a 5% hydrogen peroxide solution for 5 minutes and then rinsed in sterile water. (H_2O_2 hydrogen peroxide 100 vols concentration).
4. Seed coats were removed by hand (finger tips rinsed regularly in a 70% ethanol solution) and the top of the cotyledons removed.
5. Naked seeds were placed on an agar medium with radicle-end submerged.

In Vitro Growth. A 16-hour light/8-hour dark photoperiod was maintained throughout all stages of culture development; the "day" temperature varied between 21° and 25°C and the "night" temperature was 18° to 19°C.

Roots usually grew on the embryos and these were trimmed to approximately 10 mm in length to facilitate transfer to fresh media. Explants were transferred at 3- to 4-week intervals. Where sufficient elongation had taken place seedlings were topped and the excised shoot returned to the medium beside the original seedling.

Petri dishes (25 mm × 90 mm) were used for the first 7 to 10 days and all transfers after that were into 600-ml Agee jars containing approximately 100 mls of medium. Clear petri dish tops used for lids were held in place with thin plastic film (Gladwrap) wrapped around the jar rim.

FURTHER DEVELOPMENTS

Effect of Charcoal. A comparison was made of growth on Quoirin and Lepoivre (Q-LP) medium (3) with or without activated charcoal (Merck brand) at 2.5 gm/ litre. Shoots were rated for leaf abscission, and after 8 weeks in culture, shoot height was recorded. The numbers of compound leaves and leaflets were also recorded.

The incidence of foliar abscission was higher on the Q-LP medium without charcoal; this would have contributed to the overall lack of vigour observed on this medium (Table 1). Shoots on Q-LP+ charcoal had much larger, more normal-looking pinnae. The colour of the foliage ranged from yellow to green in both treatments.

Table 1. Summary of results after 8 weeks in culture (16 clones per treatment, 1 shoot per clone)

Medium	Clones with foliage abscission	Average height (cm)	Average leaf number	Average leaflet number
Q-LP	50%	1.3 ± 0.44	2.0 ± 1.86	5.4 ± 3.7
Q-LP + charcoal	12.5%	1.6 ± 0.40	4.0 ± 2.08	7.4 ± 4.1

Rooting Experiments. A root-initiation experiment was carried out using a small number of shoots that had been grown *in-vitro* for 4 weeks on charcoal medium after excision from seedlings. They were then grown in Q-LP medium containing 5 mg/l IBA (indolebutyric acid), 2.5 mg/l NAA (naphthaleneacetic acid), and 0.2 mg/l BAP (6-benzylaminopurine).

In all cases, shoots excised from the seedling *in-vitro* did not form roots at the base even after several months on hormone-free medium. Excised shoots placed in medium containing auxin and cytokinin were assessed after four weeks for adventitious root formation (Table 2). Some were put into potting mix, and some returned to a charcoal containing medium.

Table 2. Summary of results after four weeks on the Q-LP medium with auxin/cytokinin

Number of clones	Number of shoots	Shoots with callus	Shoots with roots in vitro
7	13	13	1

Of four callused shoots put out for rooting, two had produced roots (Figure 2). The shoot which formed roots *in-vitro* continued growth after potting up. The nine shoots left in culture did not form roots after 4 weeks although the callus became firm and nodulated.

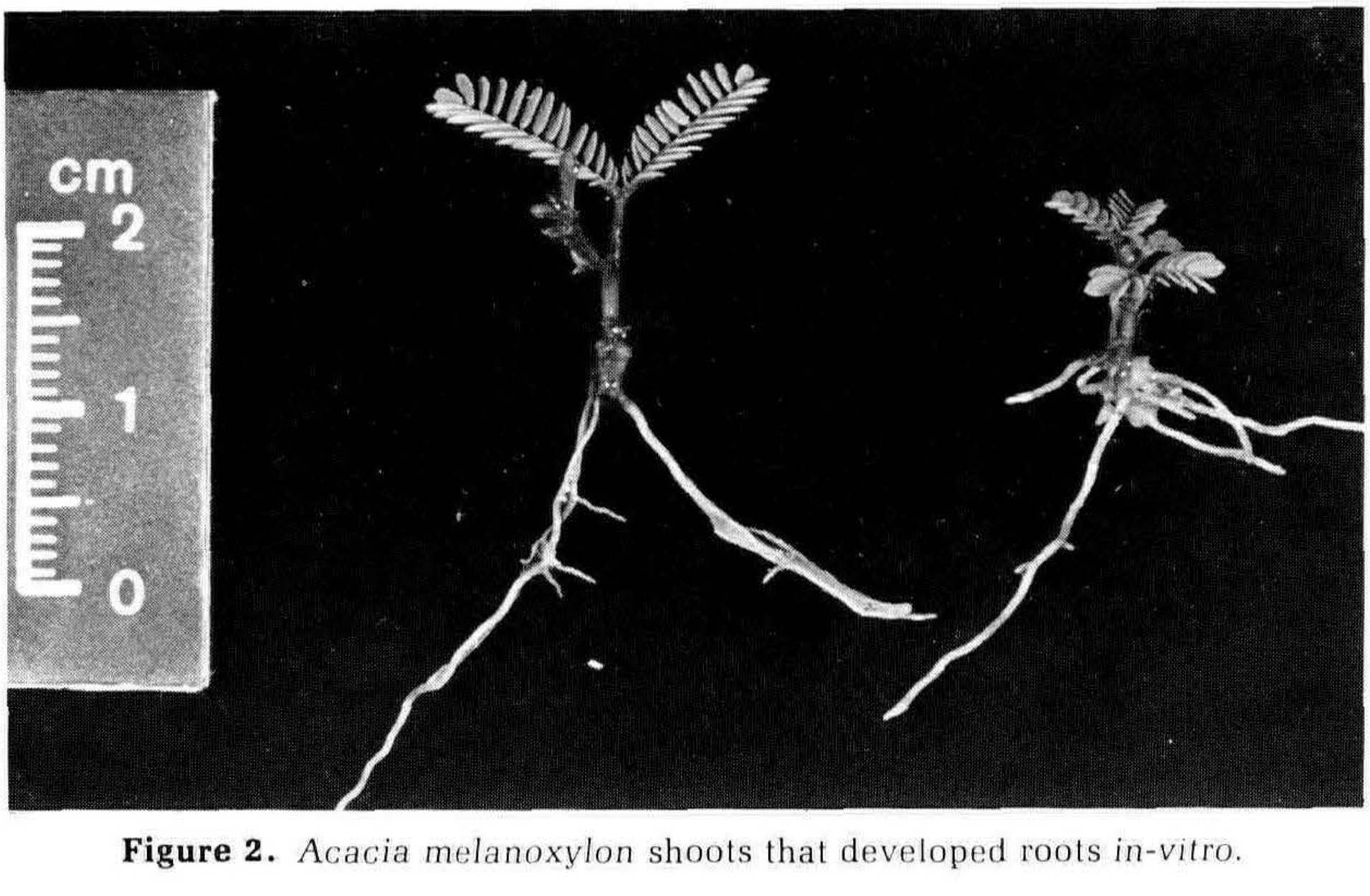

Figure 2. *Acacia melanoxylon* shoots that developed roots *in-vitro*.

CONCLUSIONS

This preliminary study shows that juvenile *Acacia melanoxylon* can be grown in sterile culture, and that shoots can be rooted in non-sterile conditions. Both the *in-vitro* and rooting stages

require further research to optimise media formulations. However, the feasibility of *in-vitro* multiplication of valuable seed from progeny-tested parents has been demonstrated. Further research will be necessary before the methods can be applied to field-grown *Acacia melanoxylon*.

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BIOLOGICAL CONTROL: DOES IT HAVE A PLACE IN PLANT PROPAGATION?

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Before the question posed in the title of this paper can be answered it is necessary to pose, and attempt to answer, two others:

(1) What is biological control? and (2) what can it achieve?

What is biological control? The term biological control can mean rather different things to different people. Like many well worked (or over-worked) terms it has been adapted and modified by various authors to suit their own particular view points. The way in which the term will be used in the present paper should be clear from the following discussion.

The basic ideas, concepts and early applications of biological control were developed primarily by entomologists who, at least 100 years ago, recognised the importance of natural enemies in regulating populations of pest species. To a large extent it is only during the past few decades that such concepts have been extended to organisms other than insects and mites. I will first discuss biological control with respect to pest insects, then consider briefly if and how it may be applied to other "pest organisms" in the broader sense.

A much quoted definition of biological control is that of DeBach (1), an entomologist: "*Biological Control* is the regulation

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A much quoted definition of biological control is that of DeBach (1), an entomologist: "*Biological Control* is the regulation

by natural enemies of another organism's population density at a lower average level than would otherwise occur."

To understand this definition properly we need to consider how insect populations change with time and the factors that influence such changes. Figure 1 summarizes the essential features. Insects (like most living organisms) have the potential for continued rapid increase in numbers under optimum conditions but in practice never achieve this except for short periods of time. Instead, their numbers tend to fluctuate around a mean which remains relatively constant. The shorter term fluctuations about the mean are determined by fluctuations in environmental conditions which include both abiotic and biotic factors. Among the latter, natural enemies are the most important.

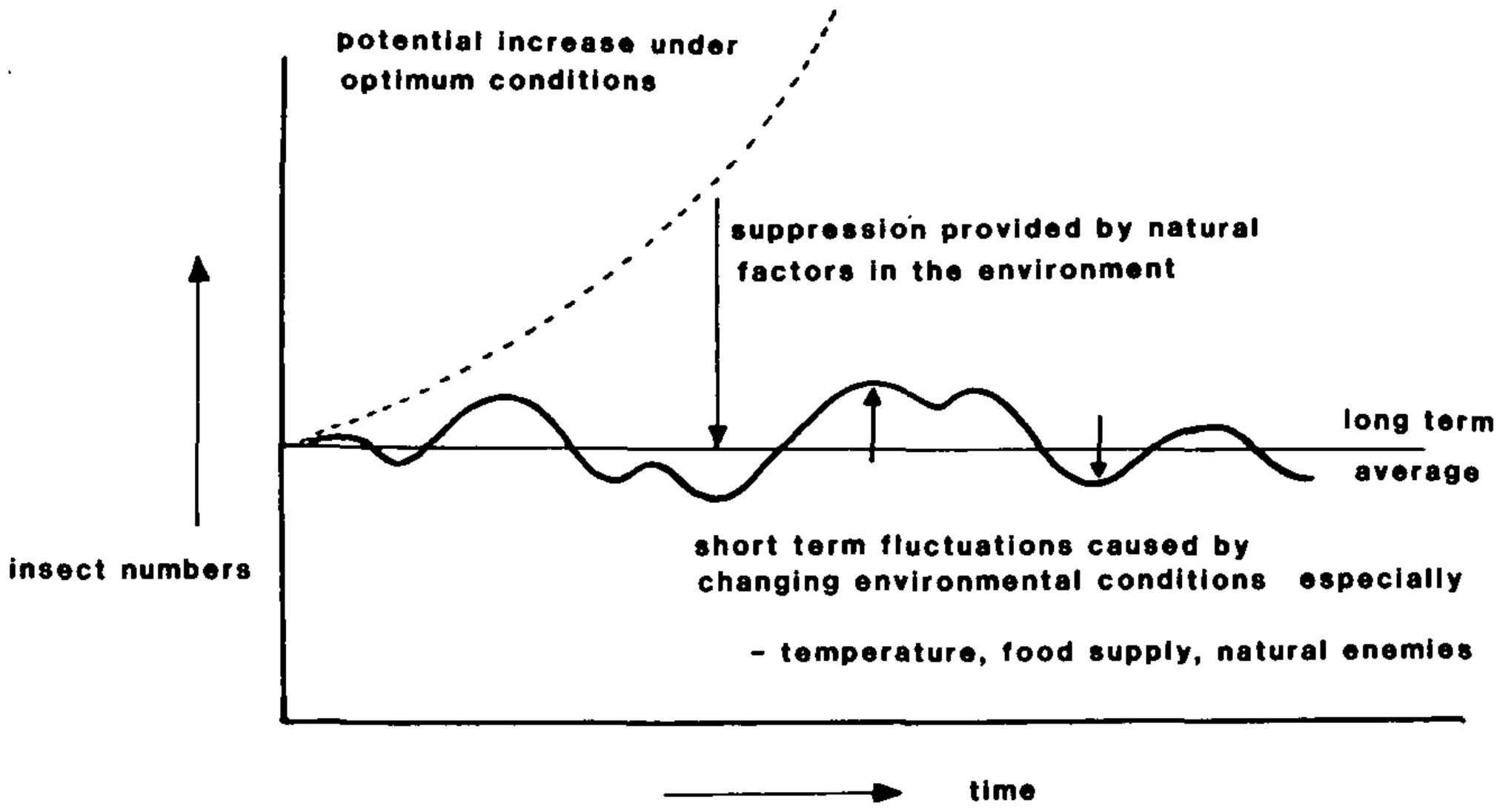

Figure 1. Natural regulation of insect numbers.

Note that in DeBach's definition of biological control, natural enemies may be an entirely *natural* element of the environment without any human manipulation. In my view it is better to refer to this simply as *natural control* (or regulation) and to reserve the term *biological control* for situations where the natural enemy component has been (or is being) manipulated by human agency. I would therefore like to offer you another (and simpler) definition of biological control.

"the use of natural enemies to suppress pest species"

This definition emphasises the element of human interaction (use) and the fact that the target species is of economic importance (pest).

Let us now consider briefly what natural enemies are. They fall under three headings: (a) parasites, (b) predators, (c) pathogens.

Parasites of insects are mostly other insects from the orders

Hymenoptera (wasps) and Diptera (flies). The larval stage of the parasite lives on or in the body of the attacked (host) insect and invariably kills it before the parasite completes its own development. All juvenile stages of insects (eggs, larvae, pupae) are subject to parasite attack but adult insects are rarely affected. All insect species without exception (including parasites) are subject to such parasitism.

Predators, on the other hand, capture and consume insects as a source of food and a predator may eat many individual insects during its lifetime. Many important insect predators are also other insects. Ladybirds are common examples, but many birds, mammals, and other vertebrates also utilise insects as part or most of their diet. Predators are usually less specialised than parasites as to their prey but this is not always the case. Some ladybirds for example confine their feeding strictly to a few species of scale insects or aphids. Among mites, predatory mites are important natural enemies of some plant-feeding mites.

Insect pathogens are micro-organisms which induce disease conditions (often fatal) in insects. Almost all groups of micro-organisms include some insect pathogenic species. Fungi, bacteria, and viruses are the most important groups. Some nematodes, although not strictly micro-organisms, also affect insects and are usually considered along with true pathogens.

What can biological control achieve? Biological control, as now defined, involves some degree of human intervention. This can take one of three forms:

(a) Introduction (or inoculation)
(b) Augmentation (inundation, or mass rearing and release)
(c) Conservation and encouragement.

Let us briefly review each in turn:

Introduction. This is the "classical" form of biological control that has been practised for many years. It involves the artificial introduction into a country or an area of a species of natural enemy that was not previously present. Once the natural enemy has been introduced it is left to fend for itself, to establish or not, to suppress the target species or not (see Figure 2). A considerable number of successes have been recorded around the world but many more failures. A relatively recent success in New Zealand is that of effective suppression of armyworm (*Leucania separata*) with introduced parasites. Similar efforts against grass grub (*Costelytra zealandica*) have been unsuccessful. Success is most likely against pests that have themselves been introduced—but there are no guarantees. What constitutes successful control? It depends very much on the circumstances. *Any* reduction in the population density of some pests (particularly indirect pests of plants, such as root feeders on ornamental plants) may be considered worthwhile but for direct

pests (for example caterpillars damaging cut flowers), even 80 or 90% control would be considered inadequate.

A big advantage of this method of biological control is that once established it should be permanent, provided the action of the natural enemy(ies) is not disrupted by, for example, the careless use of insecticides. Insect pathogens may also be considered for introduction under certain circumstances. This form of biological control is essentially the function of a research organization and, because of quarantine implications and the need to exclude hyperparasites, decisions are usually taken at a national level. There is little that the individual grower can do other than press for adequate research funding.

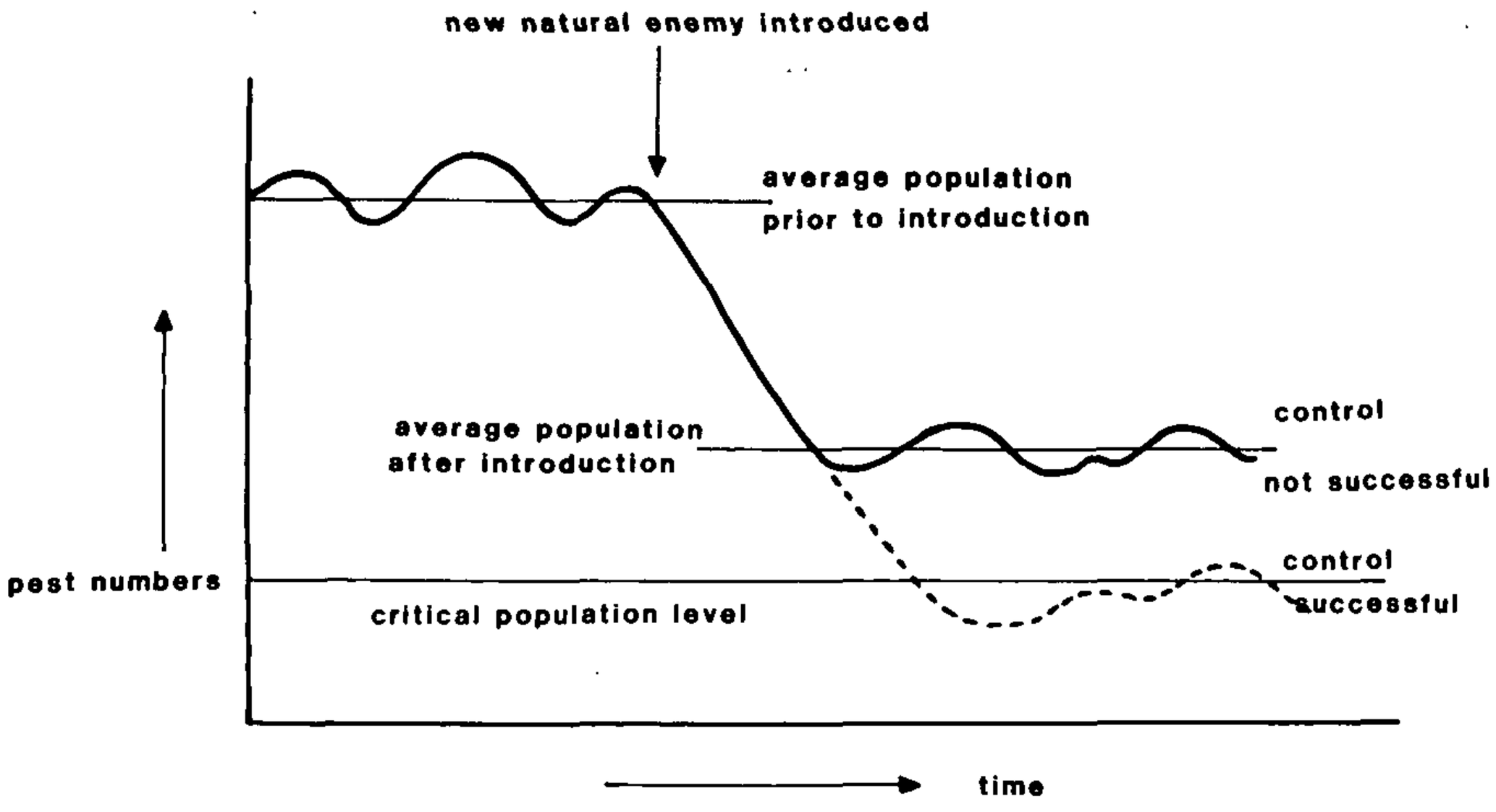

Figure 2. "Classical" biological control by introduction of a new natural enemy.

Augmentation. Augmentation involves the release into selected areas of suitable natural enemies to provide short term local control—a procedure sometimes referred to as inundation. Such natural enemies normally already exist in some form in the environment. The process is thus very much in the nature of using a "living insecticide". Figure 3 depicts the process graphically. Note that the effect wears off and the pest population recovers after a period of time.

Augmentation is obviously dependent on the ready supply of the right sorts of natural enemies which, in turn, is dependent on the development of suitable culture techniques. This has been achieved for a number of predators, parasites, and pathogens. In North America and some European countries certain commercial companies are prepared to meet the demand for these organisms and a grower can place a seasonal order but so far this has not happened in

New Zealand (the potential market here may be too small). Similarly, some insect pathogens in spore form or similar can be formulated into products for spray application to plants. *Bacillus thuringiensis* is an example.

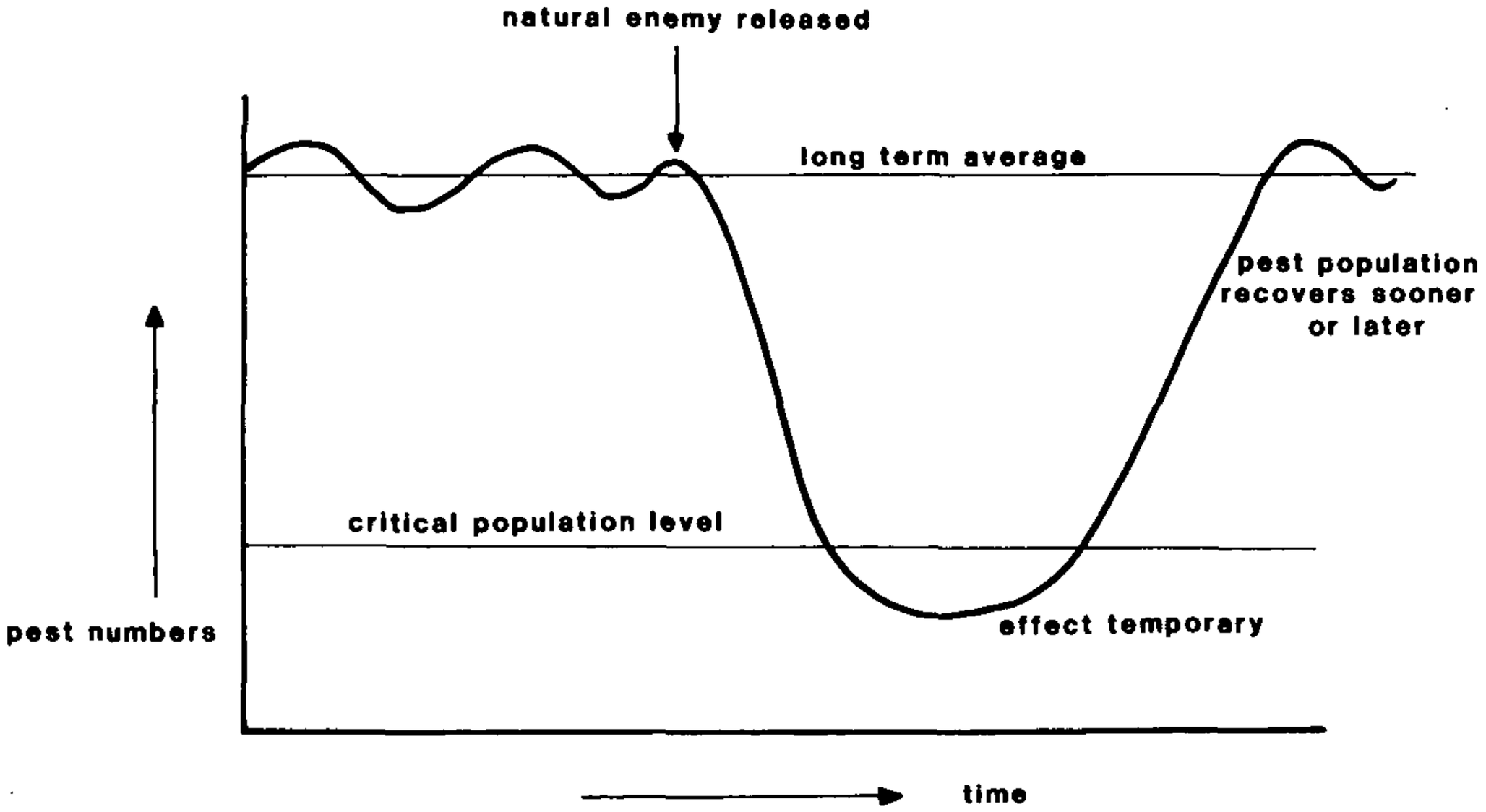

Figure 3. The effect of an inundative release of a natural enemy.

Biological control of pests of glasshouse ornamental plants by regular augmentation with natural enemies (predatory mites and whitefly parasite in particular) is now being recommended in England (3) where they are readily available at set prices. Unless the supply problem can be overcome there seems little prospect for general adoption of such methods in New Zealand.

In utilising this type of biological control procedure for a pest or pests it commonly happens that other pests (and diseases) still require chemical control. The choice of pesticides for this purpose must be carefully made to avoid harmful effects on the introduced natural enemies. Detailed information is available from such publications as those produced by the Glasshouse Crops Research Institute in England (2).

This now leads us to consider the third form of biological control; that of conservation and encouragement.

Conservation and encouragement. It is clearly important to *conserve natural enemies that have been introduced, either on a* once only basis or where regular augmentation is practised, but the same consideration may also be important with respect to natural enemies that occur quite naturally. Careless use of pesticides in particular can make pest situations worse in the long run or release potential pests from natural control (Figure 4). Apart from conservation, there is also the possibility of positively encouraging the

development of natural enemies by such measures as providing nectar sources for adult parasites or using pheromones to manipulate insect behaviour. However, progress in this direction is so far limited by inadequate knowledge and techniques.

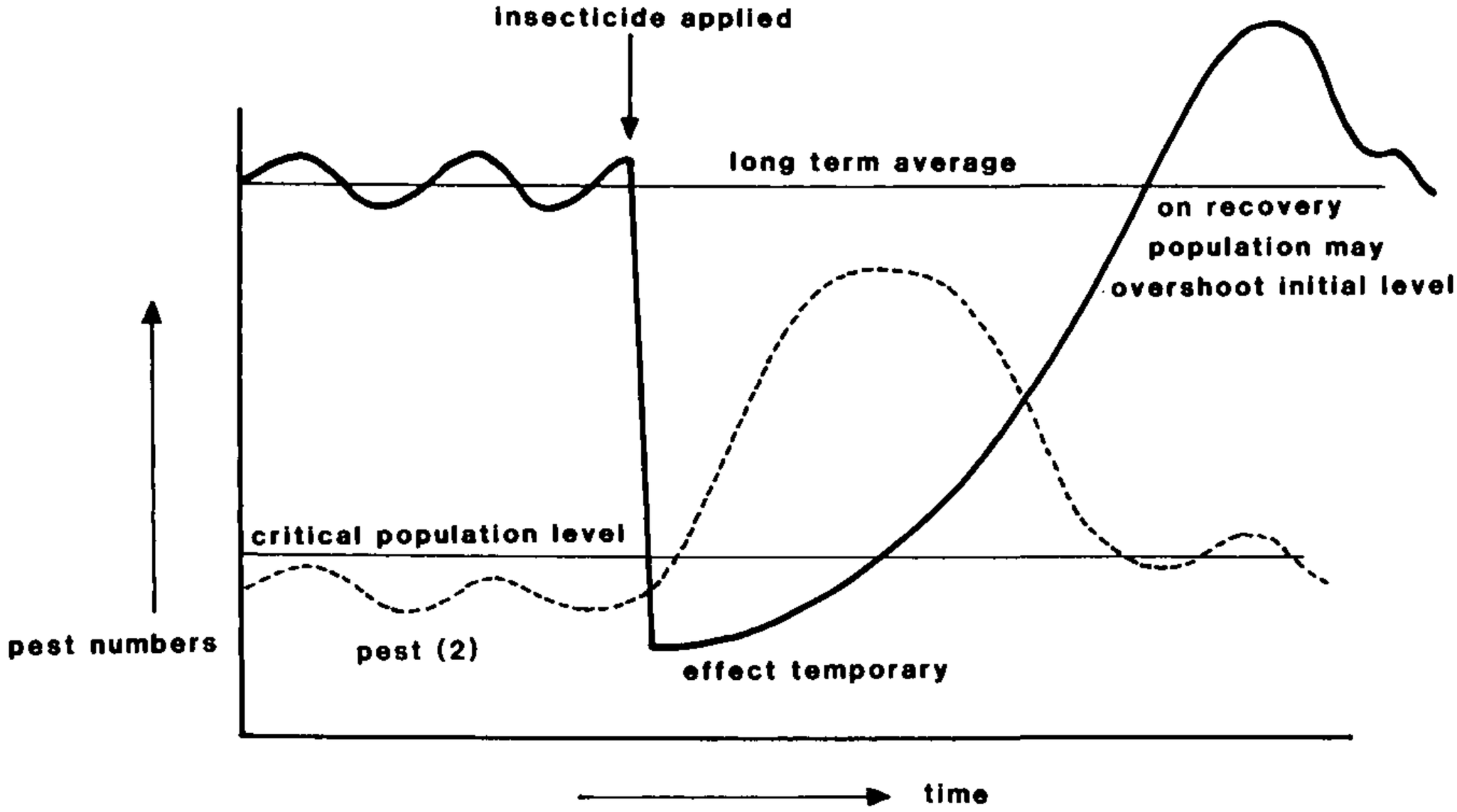

Figure 4. The effect of insecticide application on a pest population.

DISCUSSION AND CONCLUSIONS

Where does this leave us with respect to nursery plants and the plant propagator?

First, there may be a few pests that in the long term prove to be less troublesome because of improved biological control in the general environment. (The potential for this for many pests in New Zealand is still probably considerable.) However, biological control in this form rarely provides the very high level of suppression required in nursery situations so that one should not be too optimistic.

Second, there seem to be good prospects for further application of inundative techniques utilizing both parasites and predators and also insect disease organisms. The latter in particular lend themselves to the development of commercial products that can be applied in spray form and we are likely to see other types of pathogens appearing beyond the familiar *Bacillus thuringiensis*. There is for example a commercial product (Mycotal) now available in Europe based on the fungal pathogen *Cephalosporium (Verticillium) lecanii*. It requires high humidity but is effective against aphids, whitefly, and thrips (in suitable strains for each). A big advantage of such products is that they are highly compatible with parasites and predators. The critical question is whether such

techniques can provide the very high level of control of pest problems that the plant propagator requires in order to produce essentially pest (and disease) free plants. Only experience will tell. Another development that is taking place is research into genetic modification of insect pathogens to render them more virulent or in other ways to modify their action. In Canada, for example, a major cooperative programme has been established recently to work on *Bacillus thuringiensis* in this way. The potential for such developments seems almost limitless.

For the time being at least there will continue to be a need for fairly intensive use of chemicals. If these can be integrated with the biological controls that are available so much the better.

Finally, may I indulge in some speculation? Biological control of plant disease organisms is an area in which I am not competent but which clearly presents prospects for further development. Antagonism between different microorganisms has been well established since the discovery of the first antibiotics in the 1940's. Only rather limited use has followed of antibiotic substances for plant disease control in contrast to animal diseases. However, there are encouraging developments involving the use of antagonistic microorganisms for suppression of some plant pathogens. The most successful has probably been the development of the product Dygall (based on *Agrobacterium radiobacter*) for the control of crown gall (*Agrobacterium tumefaciens*). A considerable amount of work has been (and still is being) done on the potential of various *Trichoderma* species (a fungus) for control of diseases such as silver leaf caused by *Chondostereum purpureum*. Also much recent interest has focussed on soil inhabiting fluorescent *Pseudomonas* bacteria which are antagnostic to a number of fungal pathogens. Although such phenomena are easy to demonstrate in the laboratory it is another matter to utilize such organisms in a complex environment such as the soil where antagonists of the the antagonists may prevent their successful establishment. Nevertheless, there must be further potential for the expansion of this concept to other plant diseases.

Such use of living microorganisms to counter plant pathogens falls clearly within the scope of biological control but other developments are starting to blur the boundaries between different control options. Supposing, for example, we are able to isolate and chemically characterise the active substances involved in such associations, then to synthesize them and perhaps modify them chemically for greater activity. Is this still biological control? Similar considerations apply to insect pheromones which may be produced synthetically. One further example: some workers have suggested that "organic" methods of crop culture may stimulate the growth in the soil of pre-existing microorganisms antagonistic to some plant pathogens resulting in more disease-free plants. If sub-

stantiated, is such a practice cultural control or biological control? Such questions become rather meaningless but do perhaps remind us that a virtual revolution in the discipline of plant protection is a distinct possibility in the near future and that we are probably just starting to see the beginning of this.

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THE MAINTENANCE OF STOCK PLANTS

ROGER WHITE

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Whenuapai

At Lyndale Nurseries we are of the opinion that the production of good plants from cuttings begins with the maintenance of stock plants that will produce the cutting material.

By growing the majority of our stock plants on the nursery property we can be sure that:

1. The history and identity of each stock plant is known.
2. Material produced by the stock plants is free of pests and diseases.
3. Cutting material can be collected with ease at the optimum time to ensure best possible results.

As well as our regular stock beds we have employed the available space between areas on banks, etc. to grow plants suited to particular conditions. For example, on a sunny north-facing bank grevilleas thrive in very sandy soil built up from used propagating mix. Banks are also filled with leptospermums and smaller growing conifer cultivars.

In the laying out of stock beds thought should be given to accessibility when collecting cuttings. Plants need a certain amount of room to grow and we need room to be able to remove the maximum amount of cuttings from each plant. Obviously a happy medium must be struck so as not to waste valuable nursery land.

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1. The history and identity of each stock plant is known.
2. Material produced by the stock plants is free of pests and diseases.
3. Cutting material can be collected with ease at the optimum time to ensure best possible results.

As well as our regular stock beds we have employed the available space between areas on banks, etc. to grow plants suited to particular conditions. For example, on a sunny north-facing bank grevilleas thrive in very sandy soil built up from used propagating mix. Banks are also filled with leptospermums and smaller growing conifer cultivars.

In the laying out of stock beds thought should be given to accessibility when collecting cuttings. Plants need a certain amount of room to grow and we need room to be able to remove the maximum amount of cuttings from each plant. Obviously a happy medium must be struck so as not to waste valuable nursery land.

Eventual size of plants should also be considered to ensure that rows will not shade each other on any side. New plants should be kept growing as much as possible to achieve vigour for cutting later. This could involve watering during summer months in dryer areas. We have a trickle irrigation system on our newer stock bed and employ soak hoses for occasional spot watering. Mulching the beds is a useful way of retaining water, reducing weed growth, and helping in the improvement of poorer soils. The use of sawdust for this purpose has meant the older stock plants do not require any additional water in summer.

Weed control is important in any nursery environment, especially stock beds. Spraying is the least labour intensive method for us and the use of a desiccant plus pre-emergence herbicides three times a year gives satisfactory control. Paying special attention to an early spring spraying is a good idea as growth is so rampant at this time.

Stock plants must be kept free of pests and diseases to ensure that nothing undesirable is carried into the propagation area at cutting time. General spraying with a combination of sprays makes this job easier and quicker. Specific spraying can then be carried out on species with seasonal or single problems, i.e. powdery mildew on *Lagerstroemia* cultivars, mites on conifers, etc.

Feeding the stock beds is carried out twice yearly in autumn and spring by spreading 5-5-5 fertilizer around each individual plant. Although time consuming this method seems to provide good results with minimum waste.

When pruning stock plants we try to maintain as many cultivars as possible by "hedging". This method has many advantages.

1. Rows are easily kept to a manageable height for collection of cuttings.
2. By square cutting the top of the "hedge" uniform regrowth can be achieved.
3. Each plant will produce many more cuttings by being pruned.
4. Most importantly "hedging" will produce more "juvenile" regrowth and, in many species, this younger growth is what we require for successful cutting material.

This method has proved useful with *Pittosporum, Callistemon, Lophomyrtus, Metrosideros* cultivars, and others. Hedging is best carried out in winter, making sure that all necessary wood for cuttings has either been removed or is saved during pruning for use after. Species which are not hedged are generally dealt with at the time of taking cuttings. Camellias, for example, can easily be cut back in this way ensuring regrowth will occur without further pruning.

When taking cuttings off stock plants it is important to bear in mind that more wood is needed next season or sooner. Plants that are slow growing or very woody, i.e. conifers, can easily be ruined by indiscriminate pruning.

No matter how much attention we give our plants, continual removal of new growth will doubtless lead to deterioration. The life expectancy of stock plants will vary greatly among species with some "running out," possibly after four or five years of use, particularly hedged cultivars, while others may serve up batches of cuttings for many years. With this in mind a renewal programme for the stock plants should be considered.

FACTORS AFFECTING ROOT FORMATION ON *PHOTINIA* 'RED ROBIN' CUTTINGS

C. B. CHRISTIE

Department of Horticultural Science
Massey University
Palmerston North

Abstract: A discussion group met to consider why *Photinia* × *fraseri* 'Red Robin' was a difficult subject to manage in the propagation and growing-on departments of many nurseries. The stock plant management and history prior to taking cuttings was probably more important than the propagation environment in producing a well-rooted, but not heavily callused plant, provided normal requirements for light, temperature, and water are satisfied.

INTRODUCTION

It has been estimated that each year in New Zealand approximately 80 to 100,000 *Photinia* plants are used by the ornamental plant market and, in addition, further quantities are produced for export. For many years this plant has given inconsistent rooting and has been a difficult plant to train into a suitably branched specimen.

In an effort to "lessen the professional loneliness" (referred to by Dr. Phil Parvin, 1986 International President of I.P.P.S.) that may exist among individuals in the industry and within the International Plant Propagators' Society members, a forum of nursery persons with an interest in this problem was assembled to share their collective experience and see if they could put roots on this new "Aaron's Rod."

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REPORT ON DISCUSSION GROUP

The topic was introduced by a brief review of the factors affecting root formation on stem cuttings. Discussion of the rooting environment, cutting treatments, and plant factors were the focus of attention.

Few reports in the literature attempt to deal with propagation environment on rooting of *Photinia*. Laiche (7) reported that cuttings rooted equally well in soilless and soil-based propagation media. The most highly branched plants developed in media containing some clay, which is interesting as most growers in New Zealand use entirely soilless media. Invariably propagators were using some form of misting and reported that soft cuttings were particularly sensitive to moisture stress. This frequently resulted in a substantial defoliation similar to that occurring in rooted plants (8).

The band-aid type treatments that have been used to promote root formation are extensive. Ticknor (10) and Dirr (1) working with *Photinia* × *fraseri* reported that liquid auxin treatments generally produced better results than powder treatments. A closely related plant, *Heteromeles arbutifolia,* responded in the same manner (2). Wounding is often used to increase the number of cuttings rooted and increase the number of roots produced; this may take the form of either a light wound through to the more severe wounding by splitting as reported for apples (5). Plant factors, such as the type of wood, and seasonal effects were also considered. It was unanimously agreed that the wood should be as young as possible. There was, however, some variation expressed by propagators in the maturity of the ideal propagation wood, although there was agreement that the very soft bright red was difficult to maintain.

In the introduction some slides were shown that highlighted the difficulty of promoting root growth at the expense of callus growth on the base of cuttings. In some years this problem is sufficiently serious that propagators spend much valuable time lifting heavily callused cuttings, often retreating with auxin, resetting, as reported by Greever (3), and waiting to see if roots will eventually form.

Substantial variation in the speed of rooting suggested there may be important clonal differences or virus accumulation (4) worthy of further investigation.

Producing a suitably branched plant is still a challenge for many nursery operators; some ideal plants with 4 to 6 lateral shoots were on display. These had been produced by pruning back new shoot growth to the point where the nodes were tightly compressed; new growth from this region was usually most productive. Growth regulators have also been used successfully in New Zealand and overseas to promote shoot formation (6, 9) on photinia plants.

Information shared in the discussion is summarised in the following table.

SUMMARY: FACTORS INFLUENCING ROOTING OF PHOTINIA CUTTINGS

Spokesperson:			
Ian Fankhauser	Malcolm Woolmore	Barrie McKenzie	Richard Ware
Location:			
New Plymouth	Auckland	Auckland	Napier
Time of year:			
April–May	Oct/Jan/April	Sept–Nov Jan–Feb	Aug–Sept Mar–May
Type of cutting:			
3/4–4/4 ripe	soft–½ ripe	soft	soft
Size of cutting:			
8–10 cm	10–12 cm	15–20 cm	7–10 cm
Number of leaves:			
3–4	2–3	4–5	3–4
Leaf colour:			
green	red	red, some green visible	red with a green tinge
Leaf trimming on cutting:			
light	none	light/ medium	light
Treatments: —IBA.			
0.8% powder	0.1 to 0.3% powder	0.8% quickdip	0.3% liquid dip
—Wounding			
yes	yes	1cm split	yes
Rooting environment:			
—Temperature of media			
25°C	20°C	22°C	21°C
—Humidification (nozzle type)			
mist (Cambrian)	mist (Cambrian)	mist (Sage Hort)	mist (Cameron Cambrian)

—medium			
50/50 peat/perlite	90/10 pumice/peat	70/30 pumice/peat	100 pumice or 25/75 peat/pumice
—media-incorporated fertiliser			
none	Plantosan	*none*	liquidfeed
Time for rooting (weeks):			
9	3–4	6–8	2–6
Percentage potted:			
72+	90+	80+	75–80
Unrooted cuttings reset:			
no	yes (10–20%)	yes (20–30%)	no
Stockplant source:			
cutting hedge		GOLs and container stock	
Stockplant flowering:			
sometimes	sometimes	rarely	rarely
Bushy plant production:			
Trim back to just above the rosette			Atrinal—spray 7 days after trimming

CONCLUSIONS

This discussion confirmed that many factors can influence the rooting of cuttings. *Photinia* 'Red Robin' proved not to be impossible to root, but rather variable in its performance; this variation was thought to arise from plant factors, rather than differences attributable to cutting treatments and the propagation environment. The plant factors should be investigated further, including stock plant management, identification of clones with superior rooting, and branching characteristics.

Photinia × 'Red Robin' is a New Zealand-raised selection considered to be a hybrid between *Photinia glabra* 'Rubens' and *Photinia serrulata* that originated in Masterton.

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METHODS AND TIME OF BUDDING FOR PEACH NURSERY TREES

JOHN A. EISEMAN and MICHAEL B. THOMAS
Department of Horticulture, Landscape, and Parks
Lincoln College
Canterbury

Abstract: The relative success of T-budding, with and without "backwood", and of chip budding were compared at four different times for the production of peach nursery trees. Early budding resulted in the highest bud takes. There was no significant difference in success among the three methods. Budding was unsuccessful for the last budding time, regardless of whether chip budding or T-budding was used.

INTRODUCTION

In cool temperate areas the period available for T-budding peaches is restricted by the time taken for the seedling to attain sufficient girth and the limited period in which the bark will lift to allow bud insertion.

Extension of the budding season is potentially possible by the use of chip budding where there is no requirement for the bark to slip. Howard (4) suggests that a major advantage of chip budding over T-budding occurs where the post-budding period for cambial activity is limited (e.g. in England). An extension of the budding season for apples by use of chip budding is reported by Howard (4) but best results were attained during the period normally associated with conventional T-budding. Successful employment of

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chip-budding in *Prunus* is reported by Bremer (1) for peach and cherry, and Poniedzialek (5) for sour cherry.

In New Zealand T-budding is the predominate method used for propagation of peach. T-budding is a well established technique but there remains some debate as to the relative merits of whether to remove the slip of wood remaining behind the bud prior to insertion in the stock.

The objective of the trial described here was to investigate the relationship between time and method of budding. T-budding, both with and without the backwood, was compared with chip-budding.

MATERIALS AND METHODS

This trial was located in Canterbury, New Zealand, a region with a cool, dry climate. During the budding period daily temperature maximums range between 14° and 32°C and daily minimums between 2° and 18°C. This region is also subject to considerable variation in wind intensity and direction which influence temperature and humidity.

The rootstocks were *Prunus persica* 'Golden Queen' seedlings which had been direct sown the previous June (early winter). The trial was conducted within a large block of seedlings grown for commercial propagation and hence were subject to commercial management practice as reported by the authors (2).

In early February (late summer) stocks for the experiment were identified for all budding times and were selected for uniformity of girth (approximately 6 mm diameter).

Experimental design was a randomised complete block with four replicates of each of the twelve treatments. Each replicate contained twenty stocks.

Scionwood of *Prunus persica* 'Red Haven' was obtained from an adjacent orchard block on the day of budding. Four budding times were selected at three weekly intervals commencing 8 February. These dates were adjusted by one or two days if weather conditions were not considered suitable for budding.

Three budding techniques were employed: (a) Chip-budding, (b) T-budding with wood retained, and (c) T-budding with wood removed. Plastic budding ties were used. For the first two budding times the ties were removed four weeks following budding to avoid girdling resulting from trunk expansion in the stock. This was not a problem for the later times and ties were retained until leaf fall in early June.

During the dormant period the stocks were headed back to 150 mm above the bud. Budding success was evaluated on 25 September, at which time shoot growth on successful buds was about 25 mm.

RESULTS

Figure 1 shows the relative success of budding methods and the decline in bud take for the last two times. Soil and air temperatures are given in Figure 2 and indicate declining temperatures as the season progressed.

No significant difference in bud take was measured among the three budding techniques at any of the first three budding times (Table 1). T-budding at the fourth budding time was prohibited by the failure of the bark to slip. Chip budding at this time was a failure with almost zero success even though it is a method normally used when bark-lift is poor.

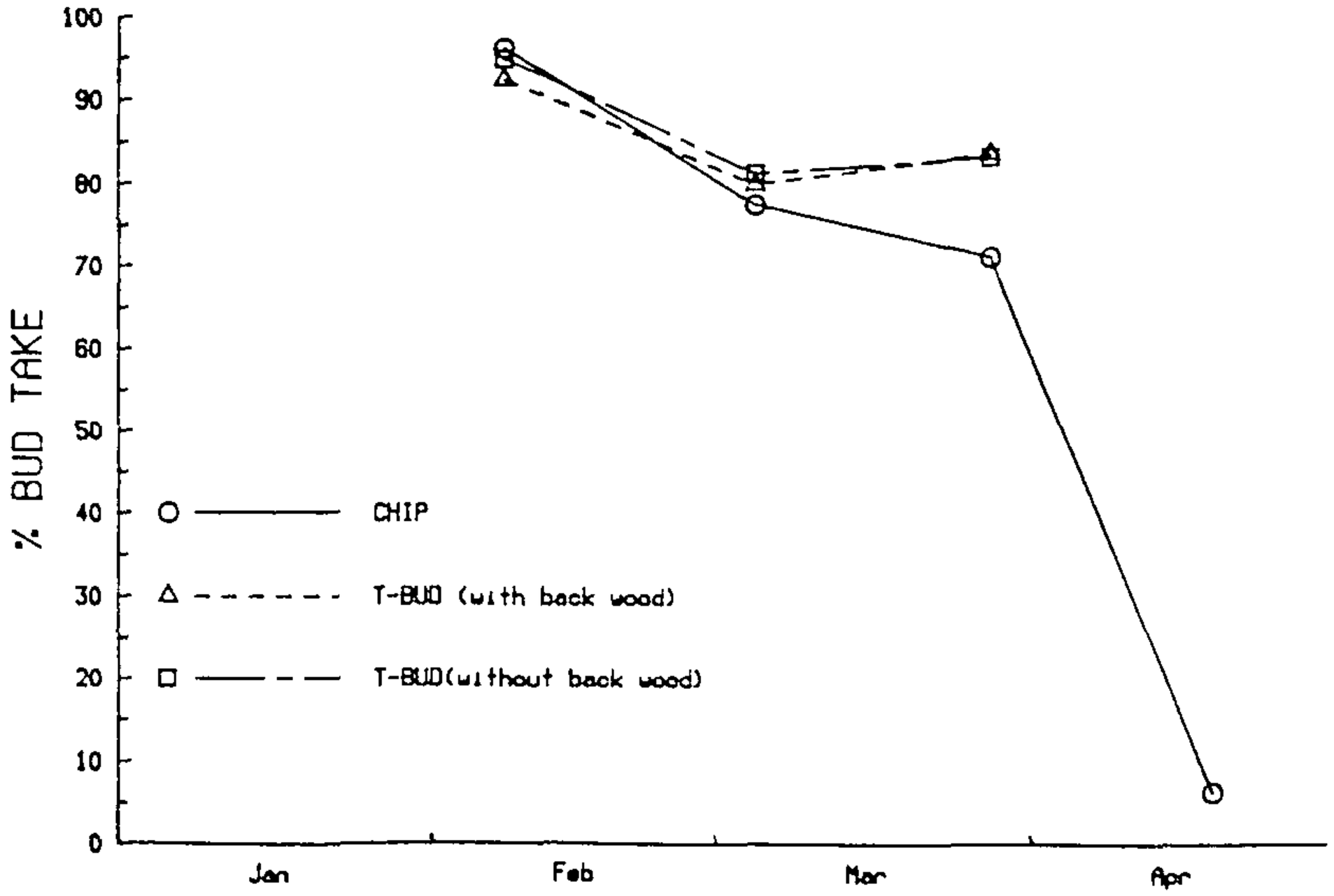

Figure 1. Relative success of the three budding methods. Note the decline in bud takes for the last two times.

Table 1. The effect of budding time and method on percentage bud take in peaches.

Date	Bud Take			Mean of Time
	Chip-bud	T-bud (with)[1]	T-bud (without)	
8 February	96.3%	92.5%	95.0%	94.6%
5 March	77.5	80.0	81.3	79.6
28 March	71.2	83.8	83.4	79.4
19 April	(6.3)	(—)	(—)	
Mean of Method	81.7	85.4	86.5	
LSD (5%) = 16.9				
Date (linear):	P = 0.004 (**)			
Between Methods:	not significant			
Interactions:	not significant			

[1] Woodpiece behind bud.

DISCUSSION

It is apparent that under Canterbury, New Zealand conditions there is considerable advantage in budding as early as possible. The observed decline in successful bud acceptance from early February (late summer) is probably a consequence of a slowing in physiological activity in the rootstock, particularly with regard to cambial activity and also to the steady decline in temperature both in the air and soil (Figure 2).

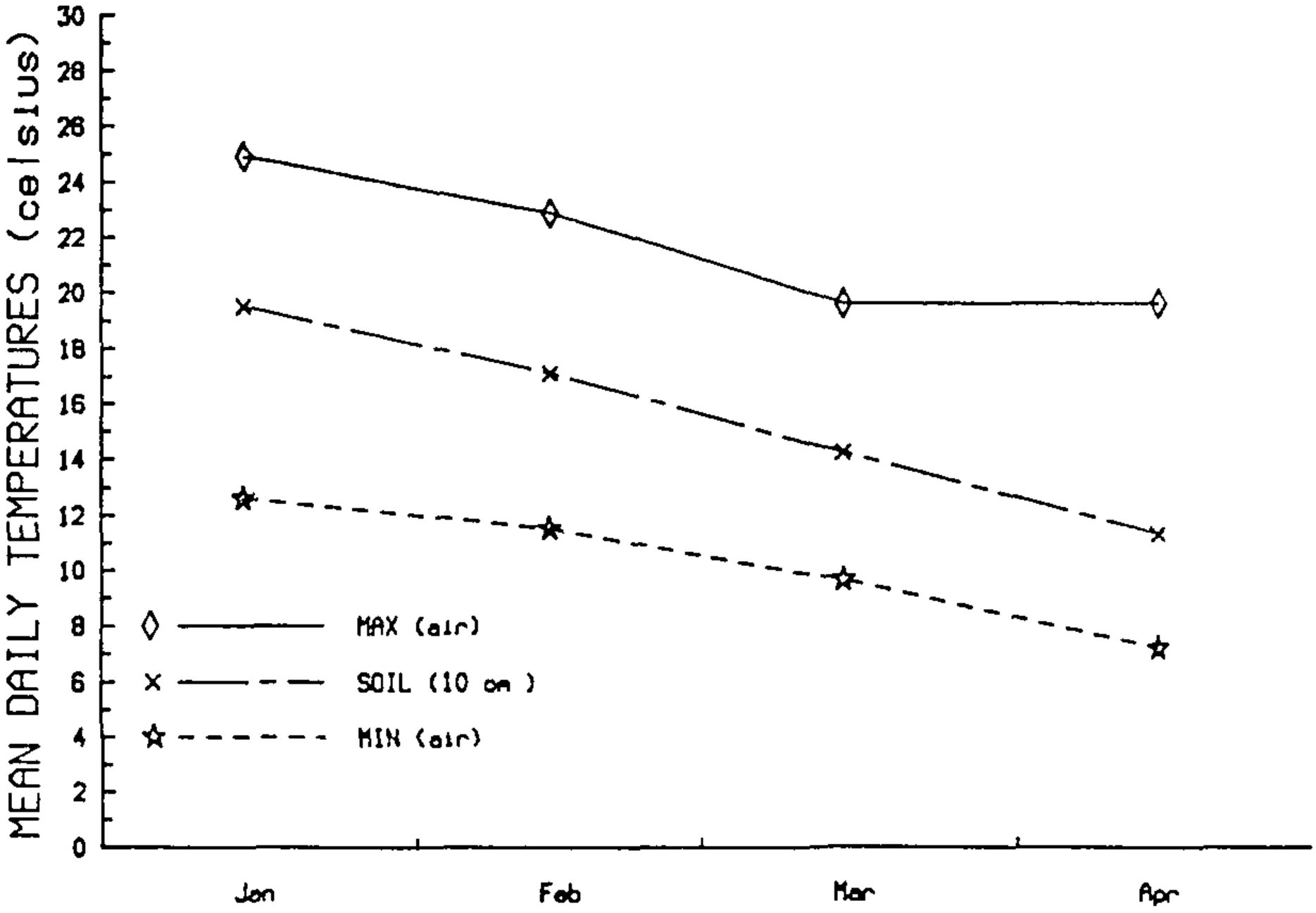

Figure 2. Mean monthly temperatures for the soil, maximum air and minimum air temperatures.

The commencement date for budding would be governed by the achievement of adequate growth in sufficient of the rootstocks to make budding practicable, as indicated by Eiseman and Thomas (2). For certain cultivars the availability of sufficiently mature budwood could also pose a restriction on commencement date. For example, in this experiment attaining mature budwood for the cultivar, 'Red Haven, for the 8 February budding was difficult, and would not have been practicable for a larger budding operation. Potentially this problem could be overcome by importation of budwood from earlier districts.

Although no attempt was made to determine the point at which a bud becomes sufficiently mature for successful budding it is apparent from attempts at December budding in Canterbury, on 18-month-old seedlings, that insufficient bud maturity in scionwood taken from local trees was responsible for poor bud acceptance, as more mature budwood obtained from the Hawkes Bay district was considerably more successful (Eiseman, personal observation).

The rootstocks for all budding times in this experiment were selected in early February for uniformity of girth based on attainment of a minimum diameter of 6 mm. In nurseries in Canterbury it is necessary in some seasons not to bud a substantial number of rootstocks in February due to insufficient girth. It is the observation of the authors that the bark on the underdeveloped seedlings continues to slip and their girth to increase later in the season at a time when both have ceased in the older rootstocks. It is therefore proposed that the rootstock selection criteria of choosing only the most advanced seedlings may have limited any opportunity to detect an extension of the budding season for any particular method. The proposed reason for this is that the seedlings used in this experiment had reached a growth plateau (quiescence), whereas if small stock had been selected for the late season budding treatments there may have been much more favourable results with them.

In their comparison of union formation between T- and chip-budded fruit and ornamental trees in the U.K., Skene *et al.* (6) cite improved bud unions and enhanced growth in the subsequent season as major advantages of chip-budding. Although not measured in this experiment poor growth or breakages at the bud union are not generally a problem in peach propagation in Canterbury. Both this observation and the failure to detect differences among the three methods of budding under comparison can probably be attributed to the prolonged autumns and milder winters experienced in Canterbury which provide more favourable conditions for union formation and bud survival than in the U.K.

The two methods of preparing the T-buds (with the 'wood-in' or with the little sliver of wood under the bark of the shield piece removed) appeared to have no significant difference. It is reported to be an advantage to use "dewooded" buds on maples and walnuts (8) and is a popular method for apricots in New Zealand. The former are all relatively more difficult to bud than peaches and would possibly have indicated improved results for the "wood-out" technique.

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SURFACTANTS AID UPTAKE OF CYTOKININ AND UREA INTO JUVENILE *PINUS RADIATA* PLANTLETS

JENNY AITKEN-CHRISTIE AND ASTRID COKER

Forest Research Institute,
Rotorua

Abstract. The effects of surfactants Tween 80, Citowett, and Silwet L-77 on foliar absorption of cytokinin and urea on juvenile *Pinus radiata* plants were examined. BAP in the presence of either 0.2% Silwet L-77 or Citowett gave a 9 and 5-fold increase, respectively, in axillary shoots at the top of the plant as well as a marked increase in stem shoot number after 18 weeks. Tween 80 had little effect.

A 1% ^{15}N-urea + 0.1% Silwet L-77 foliar application doubled the amount of nitrogen absorbed. In the absence of L-77, seedlings tolerated 5% urea, whereas in the presence of 0.1% L-77 and urea concentrations higher than 2%, needle burning occurred.

Silwet L-77 ("Pulse", Monsanto) may be a useful surfactant for foliar applications of growth regulators, growth retardants, and nutrients to other plants.

REVIEW OF LITERATURE

Foliar applications of growth regulators, growth retardants, and nutrients are frequently used in horticulture and forestry. Absorption of nutrients through foliage can alleviate nutrient deficiencies more rapidly than soil application whenever nutrient uptake through roots is restricted. Growth regulators can be applied to leaves and growing tips to alter plant form for vegetative propagation or for commercial reasons and to promote flowering and senescence. Dixon *et al.* (2) found that oak (*Quercus alba*) seedling root and shoot growth was promoted with foliar mist applications of plant growth regulators in combination with foliar fertiliser solutions. Foliar applied cytokinins have been used to induce axillary branching and basal sprouts (5, 6) while gibberellins promote flowering (4). Ineffective spray applications may be due to poor foliar absorption caused in the main by epicuticular waxes impeding penetration.

Wetting agents or surfactants are often used to improve the performance from foliar applications of plant growth regulators and nutrients. Some of the more common ones reported include Tween 20, Tween 80, Buffer X (a proprietary surfactant) and Aromox C/12

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Wetting agents or surfactants are often used to improve the performance from foliar applications of plant growth regulators and nutrients. Some of the more common ones reported include Tween 20, Tween 80, Buffer X (a proprietary surfactant) and Aromox C/12

w^3 with the concentration of surfactant used frequently left uncited (8). Surfactants enhance penetration and reduce the surface tension of water-based solutions thereby aiding wetting of tissues (8). However, other more subtle effects exist which may result in growth inhibition, stimulation, or phytotoxicity (8). At the Forest Research Institute, Rotorua, New Zealand. Dr. J. A. Zabkiewicz and R. E. Gaskin have evaluated herbicide-surfactant formulations for more effective gorse (*Ulex europaeus*) control. Silwet L-77 and Citowett were the surfactants under investigation.

This present study aims to test the effectiveness of these surfactants with cytokinin for promoting axillary bud development and with urea for increasing quantities of nitrogen absorbed in a single application.

MATERIALS AND METHODS

Experiment 1: Cytokinin spraying. Two clones of 9-month-old micropropagated *Pinus radiata* plantlets were topped and sprayed weekly (to runoff) in the glasshouse for 9 weeks with 50 mg/l benzylaminopurine (BAP) containing different surfactants. A Cambrian CSP/15 compressed air sprayer was used for spraying. The treatments were:

1. BAP plus 0.2% (v/v) Silwet L-77 (Union Carbide product supplied by Monsanto, also marketed as 'Pulse' in New Zealand).
2. BAP plus 0.2% (v/v) Citowett (York and Co. Ltd, USA).
3. BAP plus 0.2% (v/v) Tween 80 (Atlas Chem. Industries Inc., USA).
4. BAP only (BAP control).
5. Distilled water only (topped control).
6. Distilled water plus Citowett (surfactant control).

Each treatment had 6 plantlets, 3 from each clone. Axillary shoot numbers were counted after 18 weeks.

Experiment 2: ^{15}N-urea spraying. Nine month old *P. radiata* seedlings were sprayed to runoff in the nursery with 1% (w/v) ^{15}N-urea (95 atom % excess) containing either the surfactants Silwet L-77 or Tween 80, at concentrations of 0.1% and 0.5%, respectively. The control was sprayed with urea but without surfactant. Spray was delivered from a Pierce Quixspray Instant Aerosol unit and the surface of the plot was covered.

After 24 hours 5 seedlings from each treatment were washed, dried, and analysed for isotopic enrichment. Nitrogen was determined by the Kjeldahl method.

Experiment 3: Electrolyte conductivity measurements. In order to evaluate the degree of tissue damage caused by the urea-

surfactant application, electrolyte conductivity of the needle surface was measured. The electrolyte conductivity measurement includes the electrolyte contribution from unabsorbed urea as well as electrolyte leakage from the cell arising from increased plant membrane permeability. Seedlings were sprayed with concentrations of urea ranging from 1 to 7% w/v in the presence or absence of 0.1% Silwet L-77. Before and after spraying, 18 needles were harvested per treatment and placed into 15 ml of double distilled water in test tubes at 25°C for 24 hours after which electrolyte conductivity was measured using a Metrohm 660 conductivity meter. Samples were placed into a boiling water bath for 20 minutes, cooled and total electrolyte leakage from the needles was measured. Replication was three-fold. Results were subtracted from a water/blank and the percentage conductivity on the surface of the needle was calculated from: (electrolyte conductivity before boiling/total electrolyte conductivity after boiling) × 100.

RESULTS

Experiment 1: Cytokinin spraying. Table 1 shows that only the Silwet L-77 and Citowett surfactants with BAP stimulated large numbers of axillary buds after 18 weeks. However, BAP plus Silwet L-77 gave the best results. Tween 80 was surprisingly ineffective. All controls produced between 4 and 6 shoots per plantlet from the top of the plantlet (Figure 1, left). Both Silwet L-77 and Citowett produced axillary shoots at the top and on the stem of the plantlet (Table 1). In the Silwet L-77 and Citowett treated clones the bud form was also tighter and more compact than for controls (compare Figure 1, left and right).

Figure 1. *Left.* Appearance after 18 weeks of topped control plantlet sprayed with BAP and no wetting agent. *Right.* Appearance after 18 weeks of topped plantlet sprayed with BAP plus Silwet L-17.

Table 1. Effect of BAP and surfactants on axillary shoot development in topped *Pinus radiata* plantlets after 18 weeks

Treatment	Average number of shoots per plantlet at the top	Average number of stem shoots per plantlet
BAP + Silwet L-77	37.0	32.5
BAP + Citowett	20.3	8.5
BAP + Tween 80	5.3	0
BAP control	4.0	0
Topped control	4.0	0
Wetting agent control	6.0	0

Experiment 2: ^{15}N-urea spraying. More isotopically labelled nitrogen was taken up by needles when surfactant was present (Table 2). In particular, almost twice as much urea-nitrogen was absorbed in the presence of 0.1% Silwet L-77 than without.

Table 2. Effect of surfactants on ^{15}N-urea nitrogen contribution in *Pinus radiata* seedlings

Treatment	^{15}N absorbed (mg)
Urea	1.3
Urea + 0.5% Tween 80	1.8
Urea + 0.1% Silwet L-77	2.2

Experiment 3: Electrolyte conductivity. The percentage of electrolytes on the needle surface 24 hrs after spraying was highest when Silwet L-77 was present (Table 3).

Table 3. Percentage of electrolytes on *Pinus radiata* needles sprayed with urea in the presence and absence of 0.1% Silwet L-77.

Percent urea (w/v)	Percent electrolytes	
	Urea	Urea + L-77
1	—	3
2	—	3
3	2	5*
4	2	7*
5	2	14*
6	5*	17*

*Needle burning

A combination Silwet L-77 and 3% (w/v) urea application was phytotoxic. A similar result was obtained with 6% (w/v) urea in the absence of surfactant. Increases in electrolyte accretion of 5% or more were associated with visible burning symptoms.

DISCUSSION

Our results demonstrate that the presence of surfactant enhanced the BAP effect of stimulating axillary bud development and enhanced urea absorption in *Pinus radiata* seedlings and clones. Furthermore, Silwet L-77 was more effective than Citowett and Tween 80. Silwet L-77 has also been successfully used with the herbicide, glyphosate (Roundup, Monsanto) for mature gorse control (12), in $FeSO_4$ sprays applied to lemon trees (7), and in KNO_3 spray to prune trees (9).

In some instances lack of response from growth regulator and nutrient applicators may be due to incorrect choice and concentration of surfactant for a particular plant species, and inappropriate droplet size during spray delivery, resulting in poor solution retention. Organosilicone-based surfactants (Silwet L-77) were reported to give a better spreading effect on waxy surfaces than hydrocarbon based ones (e.g. the Tween surfactants and Citowett) (7). Our results confirm this.

The large numbers of axillary shoots produced in our experiment by the BAP plus Silwet L-77 spray could be useful as explants for micropropagation or for rooting. This has already been done with shoots formed after cytokinin spraying in Douglas fir (1). The shape or form of the shoot after BAP application could also be important for micropropagation. It is difficult to sterilize field-grown juvenile *Pinus radiata* shoots for micropropagation (Aitken-Christie and Steele, unpublished) because of the open form of the bud (cf mature buds). The more compact type of bud formed by the Silwet L-77 and Citowett treatments may be easier for sterilisation if spraying was done in the field.

A major consideration during spraying is the problem of leaf burn which is related to the spray solution, nutritional status of the plant, and the environmental conditions at the time of application (3). On hot days when water from the spray can be easily evaporated, unabsorbed salts may accummulate on the leaf surface and cause leaf scorching. Attempts to supply major nutrients such as nitrogen by foliar application are often unsuccessful due to repeated applications which again can cause foliar scorching. Despite these problems, yield increases following foliar urea spraying have been reported for a variety of crops including wheat, potatoes, tomatoes, fruit trees, nut trees, and soybeans (3). The absorption of urea is rapid and differs from that of most other substances (11). This feature has been used to advantage with combination macro and micronutrient applications. e.g. phosphate and iron (10). Results presented here show that less urea is required if surfactant is added, thereby making an application more economical, although multiple applications may still be necessary. Electrolyte conductivity measurements may be useful for monitoring the degree of tissue

damage and for optimising concentrations for foliar applications in order to avoid problems.

Silwet L-77 ("Pulse") could be useful for the foliar application of growth regulators, nutrients, and growth retardants to other plants. A combination spray of BAP and urea could also be beneficial to increase both growth and axillary branching. Previously unsuccessful attempts to induce flowering in *Pinus radiata*, may also be improved if gibberellin $A_{4/7}$ was applied with Silwet L-77.

Acknowledgements. The authors wish to thank Dr. J. A. Zabkiewicz for constructive discussion. Jenny Aitken-Christie thanks Lyn Holland for her technical assistance and Astrid Coker thanks Professor W. B. Sylvester for ^{15}N analyses.

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TECHNICAL SESSIONS

Tuesday Morning, December 9, 1986

The thirty-sixth annual meeting of the Eastern Region of the International Plant Propagators' Society convened at 8:00 a.m. in the Nigerian Room of the Hershey Lodge, Hershey, Pennsylvania.

PRESIDENT SMITH: I would like to share some good news with you. The preregistration this year is over 500 and with the walk-ins it is at 550. The highest meeting we ever had was 550 in 1980 at Boston, Massachusetts. So before this day is out, you will be part of the largest crowd to attend an Eastern Region Meeting or any other IPPS meeting.

I have two people I want you to meet. The first is Dr. Richard Grubb, the Secretary of Agriculture for Pennsylvania. (Dr. Grubb welcomed the attendees to Pennsylvania and wished them a good meeting.) The second person is Dick Hutton, the President of the American Association of Nurserymen and a Pennsylvania nurseryman.

I will now turn the program over to George Good, the Moderator for the morning session.

ECONOMICAL PROPAGATION STRUCTURES FOR THE SMALL GROWER

CHARLES A. HILDEBRANT

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Oldwick, New Jersey 08858

Membership in IPPS as well as various other professional nursery organizations invariably gives us opportunities to tour many prestigious nurseries. We see their propagating facilities and come away with a feeling of respect and probably a bit of envy. When we get home, however, we soon realize that even if we did have a sophisticated 30,000 sq ft propagation house, the most probable method of utilization would be by having our plants off in one corner and having a weekly barn dance in the remaining empty space.

The facts of life of the small nursery (ours is 8 acres) is that you simply do not need a large propagation facility. We currently propagate 95% of our own stock. This includes summer softwood cuttings in mist beds as well as winter hardwood cuttings in bottom-heated beds without mist. These winter, bottom-heated beds also serve to hold the young stock that we graft during the December to March period. We do 100% of our own grafting of both evergreen

and deciduous plants. Our business make-up is currently 75% retail and 25% wholesale. We anticipate the percentage of wholesale to increase in the next few years to 50%. For many years (we were established in 1923) we have used many different types of propagating structures and now have come to using two basic types.

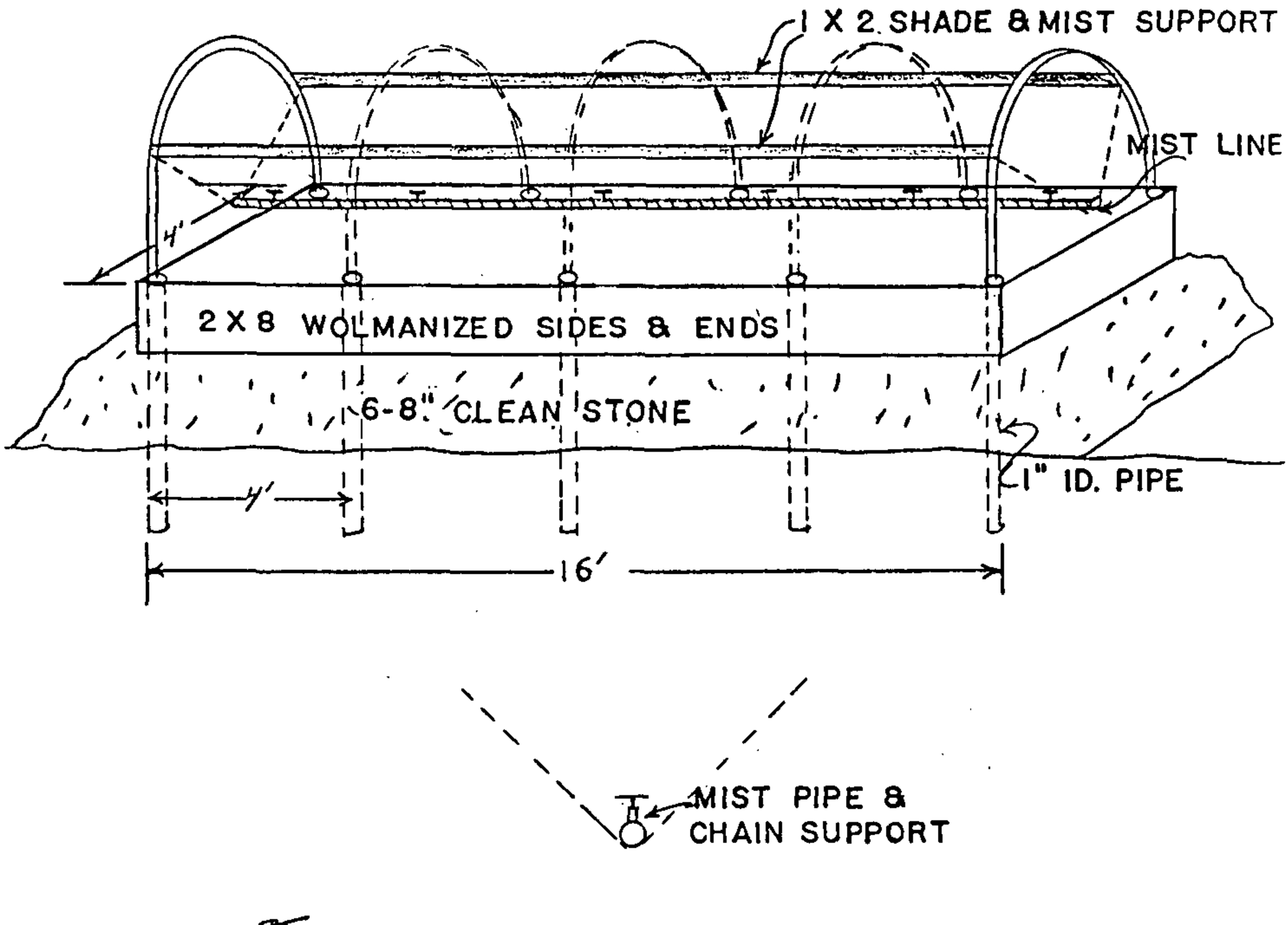
Our summer softwood work is done in an extremely simple mist bed (see Fig. 1). We start by placing approximately 6 to 8 in. of clean stone down on an open, well-drained piece of ground. On top of this we establish the level sides and ends of our bed by driving 3-ft lengths of 1-in. pipe into the ground and bolting 2 × 8 in. wolmanized lumber to them. The spacing of the pipes is approximately 4 ft apart along each side. The bed is then filled with the appropriate propagating medium. We make simple arches of 10-ft lengths of ¾ in. electrical conduit which will sit into the tops of the 1-in. driven pipes. The PVC mist line pipe is suspended by pieces of small chain from these arches. Wires may be used to suspend the pipe, but the chain gives us the flexibility of easily changing the height of our mist. Burlap or saran shade is then attached on the sides and ends as well as the top by means of 1 × 2 in. pieces of lumber simply bolted to the arches. A 1 × 2 in. board is stapled to the bottom of the burlap or saran. This serves to hold the material in place as well as making it easy to fold the whole side up to work in the bed. If wind is a problem, poly is attached under the burlap of the offending side or end to prevent blowing of the mist or drying the cuttings. The 1986 cost of materials for a 4 × 16 ft bed is about $250. The cost includes a timed mist system and it would take one person about 2 days to build this bed, including the fabrication of the mist system. This sized bed would hold approximately 5000 to 7000 average cuttings.

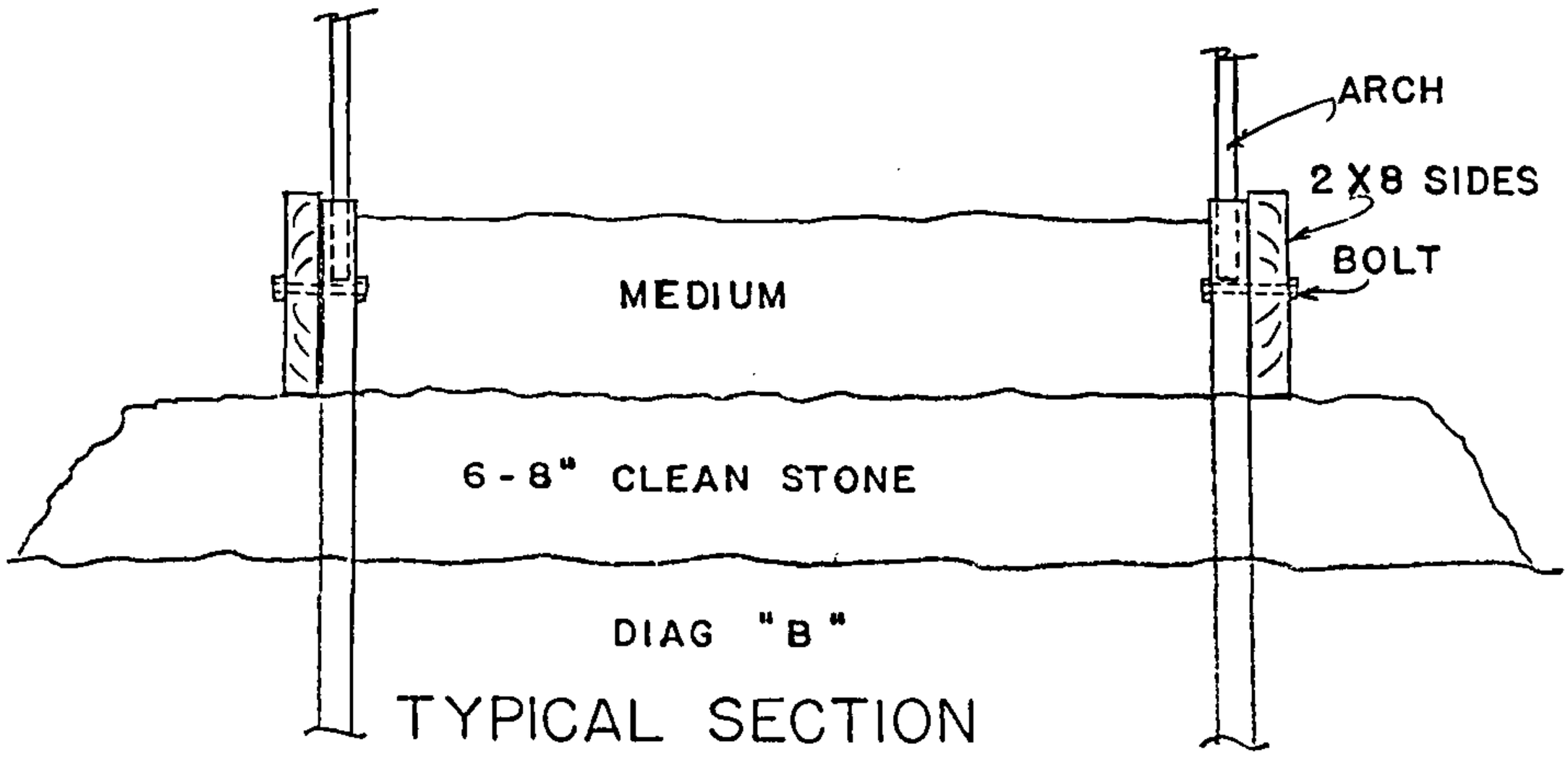
Our season of use for this bed is June through August. It is installed in full sunlight. We overwinter the rooted cuttings directly in the bed by spraying them with Wilt-Pruf in mid-November and apply a thorough fungicide drench in late November. We then remove the arches and cover the whole bed with either microfoam or poly, with a thick insulating layer of hay on top. If your beds are few and small, the microfoam is an expensive way to go; you may want to consider the poly and hay. It is important to use a good weatherproof mouse bait in the bed when you cover it to prevent rodent damage to the cuttings. We transplant the cuttings out of the bed in April.

Our winter hardwood cuttings and our grafts are handled by combining a bit of progress with a bit of history. We have reached into the past and brought forward the old sealed Wardian case concept of propagation. We then simplify it with the use of modern day styrofoam insulation, electrical bottom heat cables, and good old 6-mil poly for a top. We start with the same base stone for drainage as the summer case. On this we build a high sided box of

DIAG "A"

MIST BED PERSPECTIVE





DIAG "B"

TYPICAL SECTION

Figure 1. Details of the mist bed structure as described in the text.

wolmanized wood, cedar, or redwood, to contain our cuttings or grafts (see Figure 2). The top is tapered toward the south to allow for run-off and to maximise sunlight. We have always had these beds inside an unheated standard poly house. Other than snow load considerations there is no reason these frames could not be placed directly outdoors.

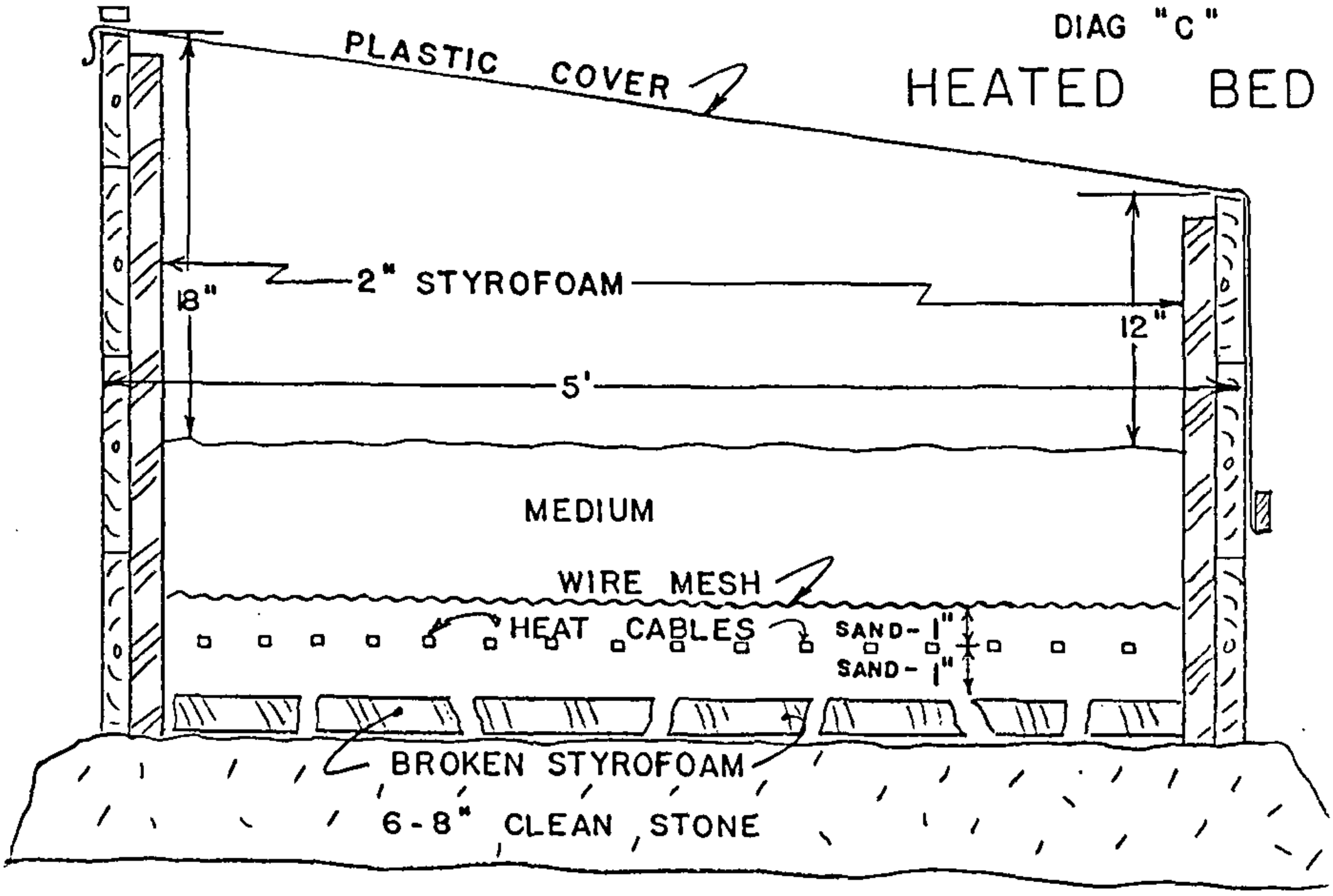


Figure 2. Details of the structure used for handling winter hardwood cuttings and grafts.

On the insides of the walls we nail 2-in. thick styrofoam insulation. Upon the gravel base we place broken blocks of 1-in. styrofoam to give us both insulation and drainage. We then apply 1 in. of clean sand on top of which we lay out the electric heat cables. In our climate (northwestern New Jersey with winter low temperatures of minus 15°F), a standard 60-ft long heating coil will give us enough coverage for a 5 × 5 ft floor area. We make our boxes 5 ft outside width and multiples of 5 ft in length. Each 5-ft section having its own cable, we can then either zone them independently, have them all hooked together, or simply leave an unused section unplugged. After installation of the cables we add another 1 in. of clean sand. It is advisable not to use a peat-sand or perlite mix over the heat cable as this tends to prohibit heat transfer. Upon this 1-in. layer we place a wire screen (½ in. mesh) to prevent a trowel from stabbing through to the electric cables. Directly on top of the screen we apply 4 to 8 in. of a 50/50 sand-peat mix. It is into this mix that we can plunge our grafts or direct stick our cuttings.

The remote bulb thermostat we use to control the coils is a Granger/Dayton #2E399. We mount the thermostat body on the outside wall of the bed, with the bulb in the middle of the bed. The bulb is placed just under the wire mesh for protection and in a representative spot for heat sensing. We are using Cox Model #2263 heating coil—60 ft lengths, 248 watts per length. We use this combination with great success and economy. Our January and February operating cost is about $6.00/5 × 5 ft section/month. This low cost is primarily due to the great insulating value of the styrofoam. We currently have the highest per kilowatt electric cost in the country in our area. Where electricity is less expensive, the operation of this type of bed would be even more attractive. Even with the high electric KW cost we have found nothing that can come near this bed arrangement for low operating cost.

The top of the case is a piece of clear 6-mil poly. Nailed to the high edge, it is allowed to drape down over the lower edge where it is stapled to a 1 × 2 in. piece of wood. This arrangement serves to hold the poly down and allows rolling the poly up when the case is open or when you are ventilating. The poly can be propped open or rolled back to any degree to allow for appropriate amounts of air passage. The seal, when closed, is amazingly good. High humidity conditions can be maintained very easily even during the coldest of weather. The 1986 materials cost to build a two section case (5 × 10 ft) is approximately $200, and can be built by one person in 8 hrs.

We are careful, use appropriate sanitation and fungicides, and have never had fungal problems. For grafting, these beds will give excellent after-graft care. One must, though, use some form of conventional heat on the understocks prior to grafting to initiate root activity. These beds are not designed to be heating powerhouses and should not be used to try to push understocks. We have a small section of a poly house partitioned off and insulated, containing a 25,000 BTU gas Modine type heater that gives us excellent results in preheating our understocks. The operating cost of this heater is minimal due to the short time it is used.

With various combinations of beds as I have described, we successfully and economically produce many thousands of high quality plants every year. Their costs are low to build, and their operating and maintenance costs after building are extremely low. We are very pleased with these structures.

CARMINE RAGONESE: Could you give us the name and source of the thermostat and cable you are using?

CHARLES HILDEBRANT: The thermostat is supplied by W. W. Granger and a source can be found in the yellow pages of most telephone directories. Home base is Chicago, Illinois, but they have many branches. The number of the thermostat is 2E399. The heating cable is from Cox in New York City. The number of the heating cable is 2263.

ROOT ZONE HEATING DESIGN CONSIDERATIONS

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Root zone heating or soil heating is an old concept being modified with new equipment to produce high quality, uniform plants in a relatively short period of time using little energy. In basic terms, the techniques used simply circulate hot water through plastic tubing to provide even heating throughout the soil medium. Two major types of root zone heating systems are commonly used. The first utilizes ¾-in. plastic tubing and the second uses the similar EPDM (ethylene propylene diene monomer) tubing. Both systems work well when engineered and installed properly (1).

The root zone heating system has a boiler, supply lines, a header system, runs or loops of tubing, a return line to the boiler, a pump, and a quality thermostat. The root zone heating system should not be the only heat supply for the greenhouse. Secondary heaters must be installed to assure warm air temperatures during extreme cold periods and to help melt problem ice and snow. Root damage from high soil temperatures may occur if the system is used to heat the whole greenhouse. Many growers found that with root zone heating (soil temperatures 70 to 80°F) air temperatures were also reduced (50 to 60°F) as the heat does not easily escape from the soil.

Some growers have run the root zone systems off present boilers, but most are installing cost-saving, highly-efficient boilers. These boilers use less water and take up smaller amounts of growing space in the greenhouse. When determining the size of boiler to use, a figure of 40 BTU/hr/sq ft of greenhouse is recommended in northeast Ohio. For example, if a greenhouse measures 100 × 18 ft, a 72,000 BTU boiler would be appropriate for the system. Remember that there must be backup heaters in case one system fails. Most of these boilers are handling water heated to around 140°F with water returning to the boiler approximately 30°F cooler. These systems usually operate between 5 and 15 lb pressure. The best quality tubing should be used at all times to prevent leaks.

If a supply line feeds more than one head system, it will be necessary to install flow control valves. If a grower has uneven heating across a root zone, consider installing throttle valves. These valves can be controlled manually to increase or decrease water flow and control temperature in the same way. Growers may wish to install one-way control valves if the systems are installed on the floor so heat does not flow to the heat zone when the pump is off. Growers have added antifreeze to a level of −5°F when starting their

systems yearly. This will help to keep the system clean longer. It is important to flush the system at least once a year to keep it flowing evenly.

Most growers installing this system are moving to rigid schedule 40 or even 80 PVC tubing in the supply lines and headers. This is done to prevent warping which could lead to cracks or leaks in the system. Some cracking occurs at joints when poorer grades of PVC are used in the system. If the system is being used on movable benches an extra length of flexible hose will prevent cracks in the headers.

Uneven heating can be a problem in root zone heating. If the hot water feeding header and the cold water return header are the same length, adding an extra length to the return header (Fig. 1) will even out the resistance and thereby even out soil temperatures. With ¾ in. tubing, where loops may occur at the end of the bench, a mixer header can be installed to prevent kinking and restricted water flow. This is simply a piece of PVC the same size as the header which will mix the water and return it to the cold water header on a more even basis (Fig. 2).

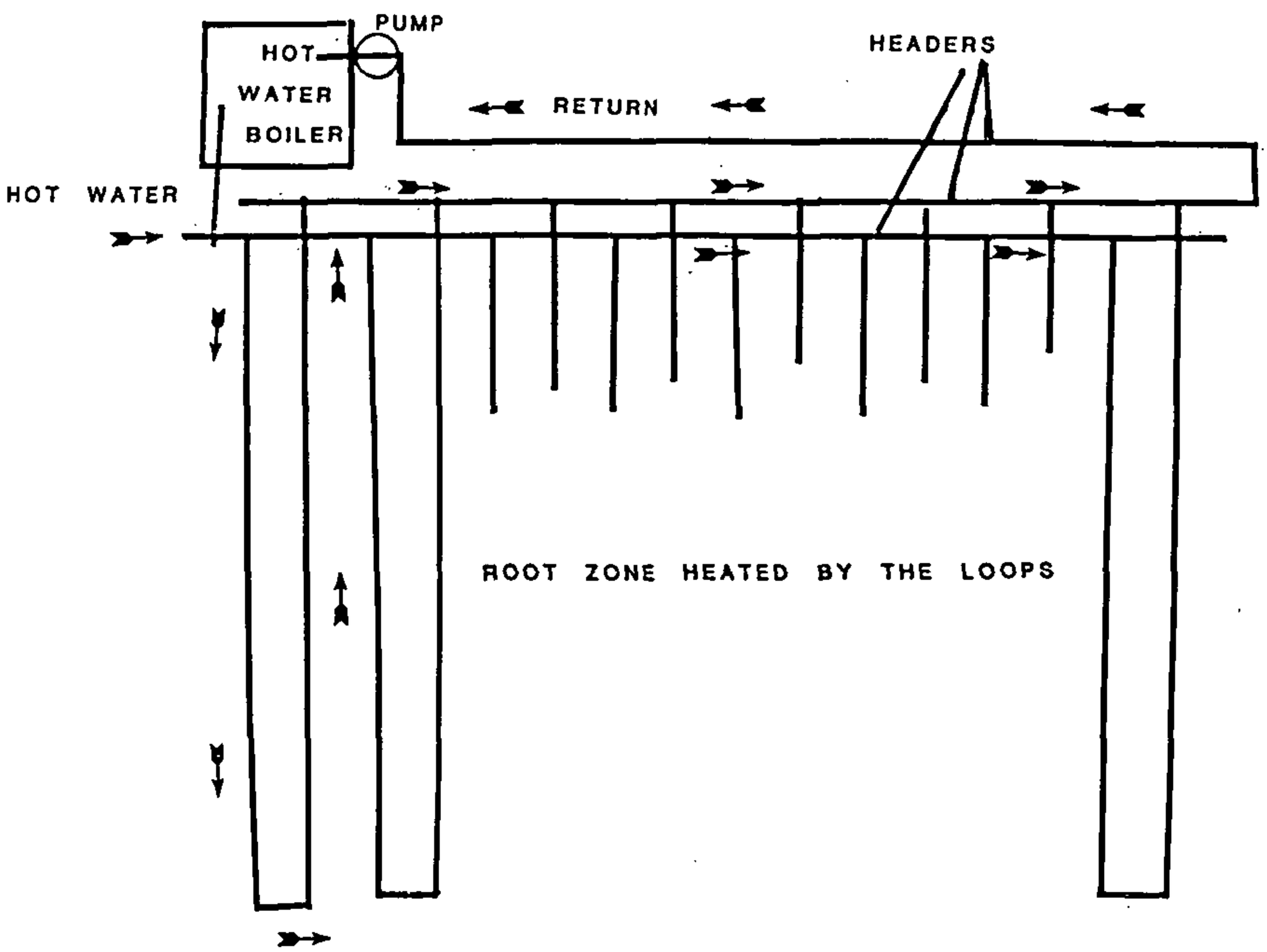

Figure 1. Layout of piping for root zone heating.

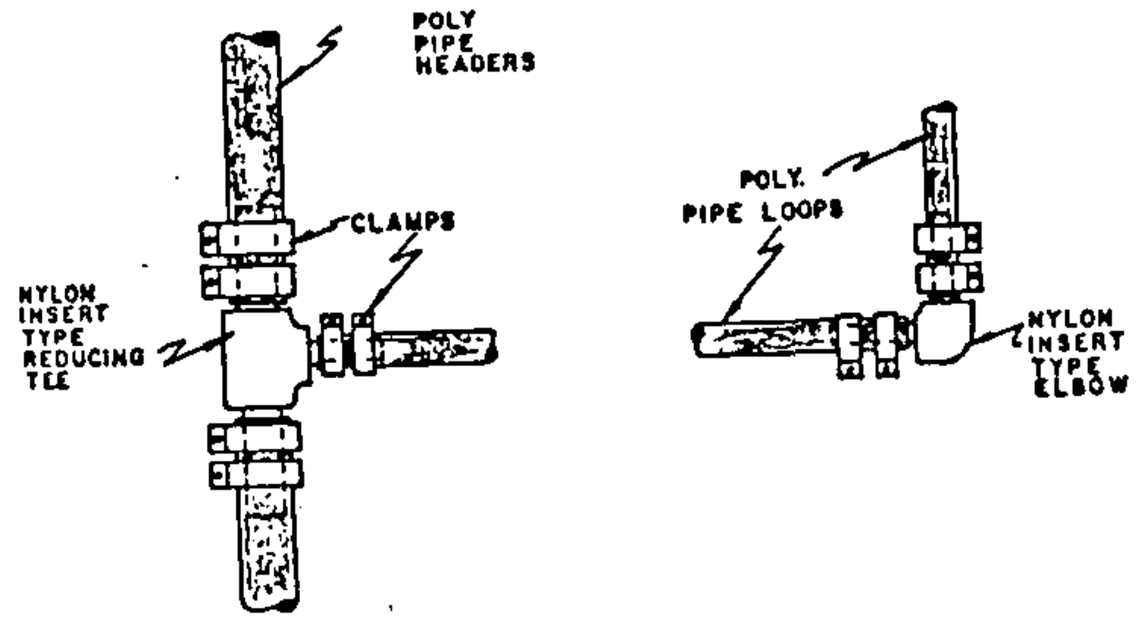

Figure 2. Layout of piping for mixing header. Solid line = cold water. Dashed line = warm water.

When installing these systems, it is best to do it in warm weather; the tubes expand in warm weather and contract in cooler weather. If tubes are installed in cool weather it is possible the lines will snake out of shape when heated. This will be less of a problem with ¾ in. tubing than with the smaller EPDM type tubing.

Most ¾ in. plastic tube systems the researchers worked with have been placed in in-ground beds. The tubes are larger so they carry more water which means fewer tubes. This system will perform just as well as the EPDM system if the tubes are buried at the same depth as they are spaced in the loop. For example, if the tubes are spaced 12 in. apart in a loop, they should be buried 12 in. deep. This allows the heat to move outward and upward and creates a more even heating pattern. The total length of each loop should be kept in the 200 ft range—sometimes longer, sometimes shorter, depending on the length of the greenhouse. Finally, the sand in which the tubes are buried has to be kept moist. This means heavier watering and, in one case, a subsurface watering system was installed. If locations were to dry out, it would create hot spots. Remember that with the ¾ in. tubing a larger header may be needed. A good rule to follow is—if you have a bed with 4 loops, a 1½ in. header should be used.

The small EPDM tube systems are the most commonly found system in northeast Ohio. These flexible tubes are designed to sit on benches as well as on the floor, or be buried a couple of inches below the floor surface. EPDM tubes carry smaller amounts of water and therefore need to be placed closer together. One grower initially placed the tubes on a bench made of styrofoam. This created uneven heating in bedding plant trays as well as in shallow flats. When 4 in. pots were placed on these benches so the pots sat on both the warm and cool water tubes, the pots showed fairly even heating in the root zone. Eventually the grower covered the tubes with 2 in. of sand and piece of black plastic to even out the heating. Growers using expanded metal benches, growing plants in rooting flats, or quart pots had no problems with uneven heating. In these cases the heat has a chance to mix in the air below the bench and create a more even heating of surfaces above.

Growers using the EPDM system on ground floors with deep rooting flats have very even root zone temperatures. The fact that these flats are watered or misted daily and the depth of the soil is equal to the spread of the tubes probably aided the even distribution of heat.

Some growers have buried the EPDM tube in a couple inches of sand or gravel. This will allow for more uniform temperatures if the grower decides to grow in small containers or shallow flats. One grower has also placed a black woven poly tarp over the beds to keep them clean and weed-free.

Growers have run into several problems. Root zone heating systems create increased humidity in greenhouses and require venting to control condensation from the roof. Research has also shown that many growers must water much heavier than before because the growing containers are drying from the bottom up. Heat loss from side walls can be a problem and growers are advised to insulate greenhouse sidewalls down to 2 ft below the surface with 2 in. of polystyrene. It is important to use extruded and not expanded polystyrene. Some growers are installing an extra loop along sidewalls if even heating is not achieved using other methods such as insulation.

In conclusion, research has shown that root zone heating systems when installed properly can help growers increase plant growth. Root zone heating systems require an independent back-up heating system. Only the best quality materials should be used and the system should be properly sized for the structure. Annual maintenance and flushing of the system is necessary to assure the best performance. More research will also be needed in the future to further system energy savings and develop more efficient system designs.

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HAROLD STONER: Have you considered using a heat pump?

RANDALL ZONDAG: One grower is using a water to air system to heat an entire greenhouse. One of the problems is that the heat pumps cannot heat the air to a high enough temperature where we want them to be. We are using the ground water as a supplemental source and pass it through a hot water heater.

HORIZONTAL AIR FLOW IN WINTER STORAGE HOUSES

CLAYTON W. FULLER

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Air movement or circulation is certainly not new to the greenhouse or nursery industry. There are many ways in which we have succeeded in doing this over the years: by opening vents, use of fans to pull air through, fan jet convectors with the punched poly tube and duct fans to create a horizontal air flow.

Horizontal air flow, or HAF, is the topic of my subject today. What exactly is HAF? It is simply air circulating horizontally in a column around the house. Fans located on opposite sides of the house provide a gentle but continuous circulation which mixes the air from top to bottom in the structure. We have used HAF in our growing houses since the advent of double poly during the energy crisis. Double poly sealed our houses so tight we found there was no natural air movement. Many articles have been written over the years about HAF in growing houses, so we will move on to cold storage houses.

Why would we want to install HAF in these structures? Are there advantages or maybe disadvantages to this method? The cold storage houses with minimum heat I am going to talk about are all 14 ft wide and range in length from 184 to 248 ft with an average height of 7 ft 6 in. at the peak.

Would HAF improve the quality of life for the plants? Because we had experienced some fungus problems in the past in these houses, it was thought that by gently moving the air around the plants 24 hr a day we could either eliminate or greatly reduce this problem, thereby not having to use as much fungicide. We did create

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HAROLD STONER: Have you considered using a heat pump?

RANDALL ZONDAG: One grower is using a water to air system to heat an entire greenhouse. One of the problems is that the heat pumps cannot heat the air to a high enough temperature where we want them to be. We are using the ground water as a supplemental source and pass it through a hot water heater.

HORIZONTAL AIR FLOW IN WINTER STORAGE HOUSES

CLAYTON W. FULLER

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Northboro, Massachusetts 01532

Air movement or circulation is certainly not new to the greenhouse or nursery industry. There are many ways in which we have succeeded in doing this over the years: by opening vents, use of fans to pull air through, fan jet convectors with the punched poly tube and duct fans to create a horizontal air flow.

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a better environment for our plants and our spraying program was lessened.

Could we create a more even temperature from one end of the house to the other during the daylight hours? Ideally a house should be built north to south for best light distribution. However, today we build them in any direction they will fit. Sometimes one end is shaded by a wood line and some of our houses are built so that they only receive full sun on one end. This uneven lighting creates uneven heating from sun light. We found that temperatures during the daylight hours showed only a slight variation from the cold end to the warm end. This was excellent, as it meant all plants in the house were receiving equal temperatures.

Would it help us in our minimum heat requirements?

a) The first answer to this is interesting because it was not one of the thoughts that readily came to mind about using HAF. It was observed that as daylight changed to darkness, the heat calories given off by the ground and plants did not simply rise to the peak, but were evenly distributed within the house. This delayed the need for supplemental heat and saved us dollars in fuel costs.

b) Could we reduce the number of heaters used to maintain our minimum heat requirements? Foremost on every businessman's mind is capital outlay, maintenance, and cost of fuel. It is our experience that—yes, the number of units required is lessened. Each of our houses has one 150,000 LP portable heater located at one end (as noted earlier, the largest of these houses is 14 by 248 ft). We found that with HAF this single unit was sufficient to maintain our required temperature—having only a 2 to 3°F variation from the burner end to the farthest point. Because of the minimum air flow through the fans, it was observed that the temperature at the burner end was higher during burner operation, but within a few minutes of shutdown the temperature had equalized. Many dollars were saved with less heaters, piping and wiring required.

Placement of fans and size. In houses up to 188 ft in length we use two 12 in. duct fans located on opposite sides of the house. The fan at the burner end is placed 20 ft from the burner, the burner being located at the side of the entrance, 2 ft from the sidewall, and 30 in. off the ground. The second fan at the far end was placed 10 ft from the end wall, ensuring that the column of air would reach the end and still have enough area to swing and come back the opposite side. The second fan is also 2 ft from the sidewall and 30 in. off the ground. The fans are secured to ½ in. EMT conduit pipe that is driven into the ground. Our 248 ft houses have two 14 in. duct fans installed in the manner described.

Cost of fans and installation. An important consideration with any project is cost. At the present time we are paying $27 for a 12 in. fan, $35 for a 14 in. fan, and with wire and labor costs the total cost of installation is approximately $70 per fan.

Did HAF perform? With the data that we collected during the previous season, the answer for us would have to be **YES.** Every house had a high-low thermometer mounted inside and a high-low thermometer was also mounted directly outside each house. Two 248 ft houses had soil probe recorders placed in a container at the end farthest from the burner. These two houses were used to collect the data presented in Table 1. The inside and outside temperatures were recorded daily, as was the type of weather. The soil probe charts were changed weekly. The HAF fans were turned off in house No. 19 for a period of time to record whether HAF was really working.

Table 1. Temperatures recorded with or without horizontal air flow (HAF).

#19 house no HAF[1]

Date	Weather	Outside		Soil probe	Burner end		Far end	
		H	L		H	L	H	L
2/10/86	Ptly cloudy	38°	10°	32°	62°	30°	46°	30°
2/11/86	Snow	34°	22°	29°	64°	30°	62°	30°
2/12/86	Sunny	30°	10°	29°	48°	30°	44°	26°
2/13/86	Sunny	32°	10°	30°	56°	30°	48°	28°
2/14/86	Ptly cloudy	28°	12°	30°	58°	30°	44°	26°
2/15/86	Ptly cloudy	28°	20°	31°	54°	32°	53°	31°
2/16/86	Sunny	26°	18°	30°	48°	30°	32°	28°
2/17/86	Sunny	43°	13°	31°	63°	30°	60°	28°

#20 house with HAF[2]

Date	Weather	Outside		Soil probe	Burner end		Far end	
		H	L		H	L	H	L
2/10/86	Ptly cloudy	38°	10°	36°	50°	34°	64°	32°
2/11/86	Snow	34°	22°	36°	62°	34°	54°	32°
2/12/86	Sunny	30°	10°	37°	46°	32°	40°	30°
2/13/86	Sunny	32°	10°	36°	52°	32°	50°	26°
2/14/86	Ptly cloudy	28°	12°	37°	48°	34°	58°	28°
2/15/86	Ptly cloudy	28°	20°	37°	52°	34°	54°	32°
2/16/86	Sunny	26°	18°	36°	40°	34°	46°	32°
2/17/86	Sunny	43°	13°	36°	47°	34°	64°	31°

[1] House #19 and #20 set side by side.
[2] Far end faces south-south-east.

CONCLUSIONS

I should explain that we are in a zone where temperatures sometimes drop and stay at unacceptable levels for container plant storage. Therefore, each of our storage houses has supplemental heat. Although HAF seems to have performed very well for us, there may be further refinements needed in the future, i.e. fan size,

house size, and burner number. Certainly some aspects of HAF should be of help to growers winter-storing plants. Whether HAF would be of benefit in milder or colder zones, only further experiments will disclose.

GEORGE GOOD: Could you give us some indication of the types of plant material you overwinter?

CLAYTON FULLER: We are overwintering rhododendron, azalea, holly, cotoneaster, *Euonymus fortunei* "types," broom, and hydrangea.

JIM WELLS: Does it take 12 hr for the air circular system to establish?

CLAYTON FULLER: Yes, the air flow should be so slow that one can not feel it. It will take 12 to 24 hr to establish. We were only working with a 16 HP motor.

JIM CROSS: Have you noticed any difference in your water requirements?

CLAYTON FULLER: No, the water requirements are the same since we are not bringing any air from outside.

ANDY DUVALL: How low do your outside temperatures get and what temperature do you try to maintain your houses?

CLAYTON FULLER: We have been down to a little below 0°F. We like to keep the container soil temperature no lower than 30 to 32°F. We have tried lower but it takes too long to recover the temperature. The same goes for the air temperature.

A COMPARISON BETWEEN SAND/POLYSTYRENE AND PEAT/POLYSTYRENE MIXES FOR ROOTING ORNAMENTAL SHRUB CUTTINGS

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Abstract. Cuttings of 8 woody shrub species were rooted under intermittent mist in mixes containing 0, 25, 50, and 75% (by vol) of polystyrene pellets with 100, 75, 50, and 25% of either sand or peat. Based on evaluation of rooting percentage and(or) on an index of root mass and quality, rooting performance of all species was better and(or) more uniform in sand/polystyrene than in corresponding peat/polystyrene mixes. Inhibition and greater variation in rooting in the peat/polystyrene mixes seem to be associated with low pH, non-uniformity, and excessive moisture in these mixes.

INTRODUCTION

The type and composition of the propagating medium is important for rooting cuttings of many woody plants. Although numerous combinations of rooting media have been developed and used by commercial nurseries, there is continuing need to evaluate and introduce new combinations.

Propagation media may often be improved by the addition of coarser materials (2,6). Polystyrene (PS) is presently being used by certain propagators as a supplement in rooting mixes (1,4). Due to its light weight, high porosity, ready availability, and low cost (4), it has the potential of becoming an important material in the nursery industry.

In this study, rooting of cuttings of eight woody shrub species was compared in media containing various proportions of PS mixed with sand (S) or peat (P).

MATERIALS AND METHODS

During the growing season of 1985, leafy cuttings of the current season's growth were removed from the following species (rooting period in brackets): *Deutzia scabra* (July 16 to August 9); *Euonymus fortunei* 'Coloratus' (July 24 to September 5); *Forsythia* × *intermedia* 'Lynwood Gold' (July 3 to 22); *Weigela florida* 'Variegata Nana' (July 23 to August 16); *Buxus microphylla* (July 10 to September 23); *Potentilla parvifolia* 'Gold Drop' (August 22 to September 6); *Spiraea* × *bumalda* 'Froebelii' (August 21 to September 6); *Cotoneaster dammeri* 'Coral Beauty' (July 3 to 22).

All cuttings were treated with Seradix No. 2 (0.3% indolebutyric acid) and inserted in mixes containing 0, 25, 50, and 75% (by vol) of PS pellets with 100, 75, 50, and 25% of either S or P. The PS

pellets were mostly 4 to 6 mm in diameter, ranging up to 15 mm as a maximum size.

Mixes were contained in plastic trays (46.0 × 46.0 × 18.5 cm) each with 2.5 cm of crushed stone at the bottom. Rooting occurred in a lathhouse under intermittent mist controlled during the daytime by a time clock (4 to 8 sec/8 min). Captan (2.5 g/liter) was applied at time of cutting insertion, followed by Captan or Benlate (0.5 g/liter) applied alternatively once per week.

The experimental design was a factorial with four levels of PS and two types of mixes (S- and P-based). Within a species, there were five replications, each with 12 or 15 cuttings per experimental treatment. Rooting percentage of each species was determined, and also a visual index of root mass and quality according to the scale: 0, no rooting; 1, callus but no roots; 2, poor rooting; 3, fair rooting; 4, good rooting; 5, excellent rooting.

RESULTS AND DISCUSSION

Data in Figures 1 and 2 show the rooting percentages and indices, respectively, for each of the 8 species evaluated; horizontal bars indicate data means.

Cotoneaster dammeri, 'Coral Beauty', with a rooting percentage of 98.5% (mean over all treatments), was the only species for which rooting percentage was not significantly influenced by any of the rooting mixes (Fig. 1). All other species in S/PS mixes had mean rooting percentages of 98%, except for *Euonymus fortunei* 'Coloratus' with 79%. Varying the proportions of PS in S resulted in little or no variation in rooting percentages of each of these species. However, corresponding mean rooting percentages were lower in P/PS mixes. Varying the proportions of PS in P resulted in wide variations in rooting percentages. There was a tendency for rooting percentage to increase with increasing proportions of PS with P (Fig. 1).

Mean rooting indices (Fig. 2) in all species except *Spiraea* × *bumaldi* 'Froebelii' were significantly higher in S/PS than in P/PS mixes, and also tended to increase with increasing proportions of PS in the mixes. Analysis of variance showed that for most species there were significant interactions between levels of PS and type of mix base for both rooting percentage and root index. This suggests a complex relationship between species rooting response and mix formulations.

In this investigation, the pH in P/PS mixes ranged from 3.7 to 3.9 and from 7.8 to 8.1 in S/PS mixes. Studies with a limited number of herbacous species indicated superior rooting at a pH near or slightly above neutrality (3,5); the addition of ground limestone to acidic media improved rooting (3). This evidence may explain the poorer rooting response in P/PS mixes but does not account for the

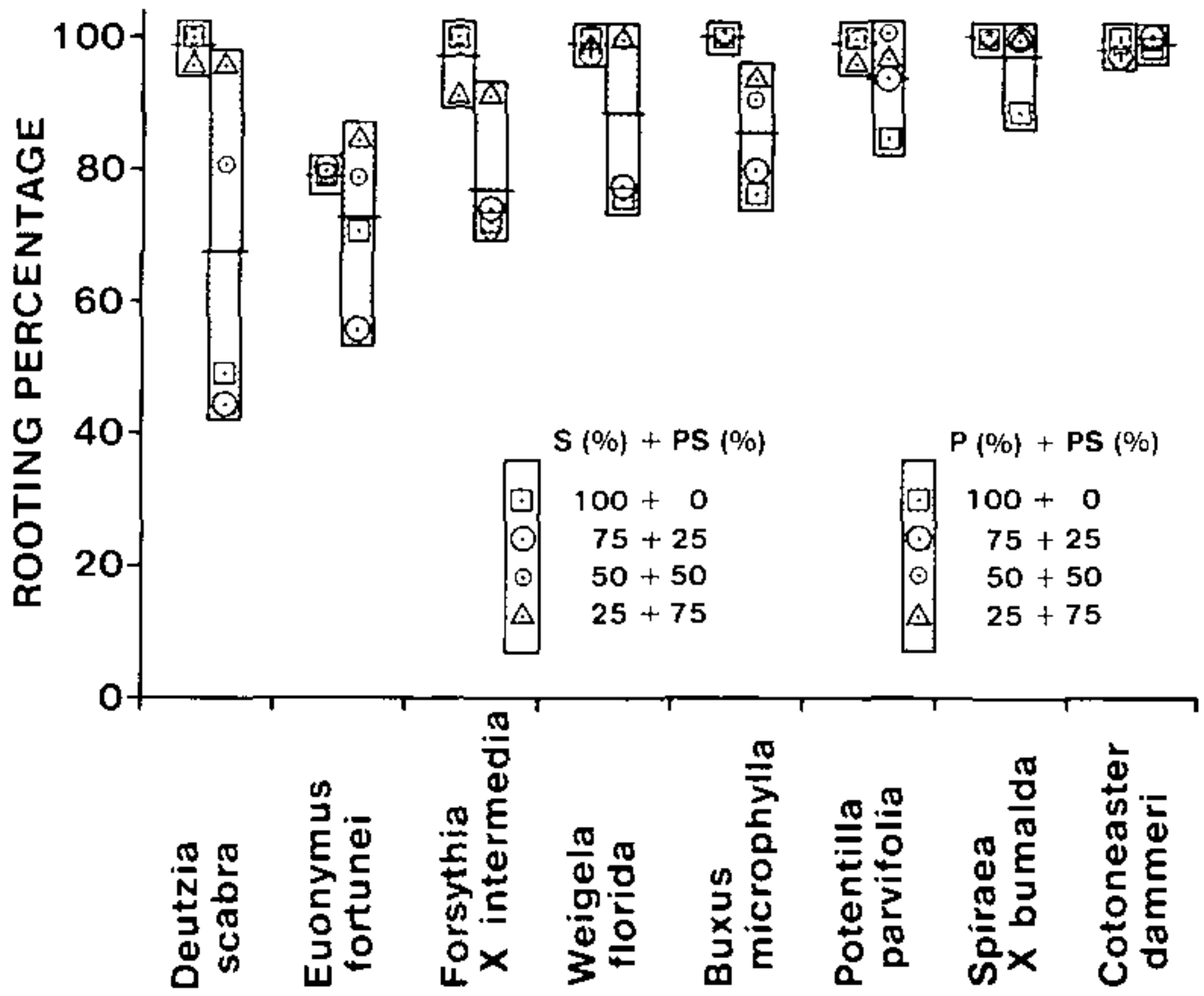

Figure 1. Rooting percentages of cuttings of eight shrub species in mixes containing various proportions of polystyrene (PS) with either sand (S) or peat (P). Horizontal bars indicate data means.

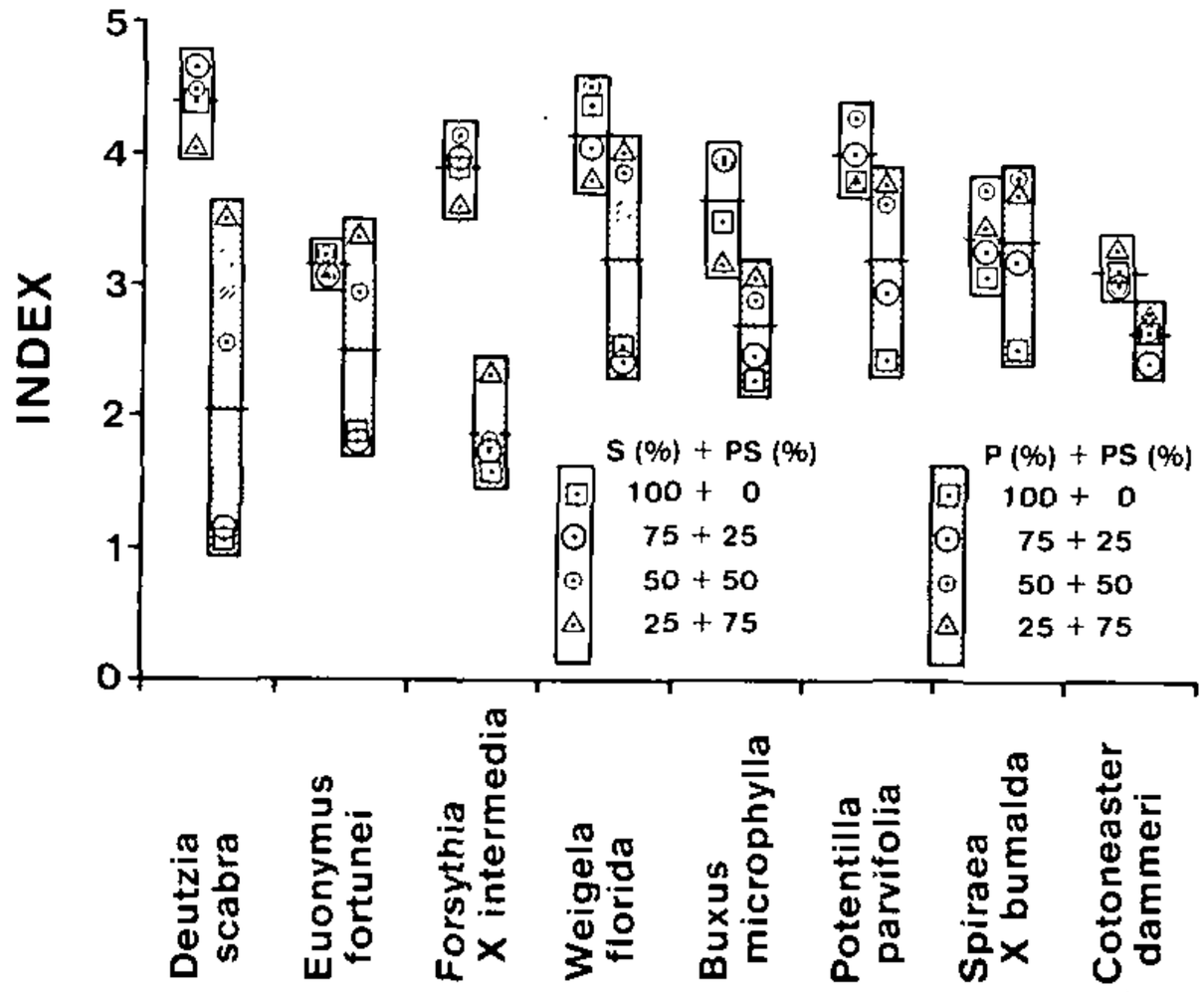

Figure 2. Rooting indices of cuttings of eight shrub species in mixes containing various proportions of polystyrene (PS) with sand (S) or peat (P). Horizontal bars indicate data means.

variability in rooting due to various proportions of PS with P. While pH adjustment of rooting media is a common practice in the production of ornamental floriculture crops, this is normally not the case within the Ontario nursery industry. Further studies designed to evaluate the influence of pH on rooting of woody species would be worthwhile.

Cook and Dunsby (1) and Matkin (4) indicated that problems of mixing PS with other media ingredients were due to the low density and water repelling property of PS. In this study, PS was difficult to

mix uniformly with S or P. There tended to be an excessive accumulation of PS on the surface of the mixes, which increased with increasing amounts of PS. Although not observed with S/PS mixes, the wide variance in rooting of most species in P/PS mixes seems to be associated with the non-uniformity of these mixes. It was also observed that the P/PS mixes tended to remain too wet. Since PS repels water (1,4), the excessive moisture in the P/PS mixes was due primarily to the moisture holding ability of P and also to the higher porosity in these mixes (4).

Acknowledgements. The technical assistance of Bob Hamersma is appreciated.

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JOE DALLON: Just a comment on the mixability of the polystyrene. If the materials to which it is mixed are wet you can easily mix sand and peat to 25% without any problems.

PETER VERMEULEN: Just a caution on the use of polystyrene, especially with the air movement ventilation that we are going to now. It floats in the air and may be getting it into your equipment.

SELECTING, GROWING, AND HYBRIDISING SPECIES OF DAFFODILS

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Some of you may be mildly surprised to see my name associated with daffodils rather than rhododendrons, misting, hormones, wounding or similar topics. How has this come about? Most nurserymen, I feel certain, do not plan to retire. I did not. I thought that eventually, in the distant future, I would perhaps collect the mail daily, make a few pungent comments to those who really do the work, and then move off to examine an unusual plant I had noticed the day before. But this was not to be.

Our nursery began in 1956 at Red Bank, New Jersey. We started with an open field, in which a few pegs were placed to indicate roads, frames, etc. We propagated a crop of rhododendrons and in 1957 began to plant out out first beds. Twenty years later we had reached a point at which we were able to help host the summer meeting of the IPPS Eastern Region. That year, 1976, was the apogee of our New Jersey nursery. The previous year we had decided to move, and a farm on the edge of the Blue Ridge Mountains near Brevard, North Carolina had been purchased. Stock moved briskly from New Jersey to North Carolina, and the land in New Jersey quickly reverted to nature with a wonderful array of Michaelmas daisies. The North Carolina nursery grew apace.

It had been planned that I should go to the new nursery first, but medical problems made it essential for me to remain in New Jersey so Jeremy went in my place. In passing, this was one of the very best decisions that we made for it enabled the nursery to be laid out by a young fresh mind. I remained in New Jersey to be near my doctors.

In two years the nursery in New Jersey was gone. What was I to do now? Five operations and my need to stay near New York clearly indicated a complete retirement. Accordingly, the full responsibility for the new nursery was given to Jeremy and I looked about for something of interest, appropriate to my limited capacity, and of course, horticultural.

My career had commenced with the mass production of alpine plants of the easier types, and I found that I liked plants of a limited stature with possibly cultural and propagation quirks which required careful study in order to succeed. In addition, the family had given me as a present some years ago, a greenhouse attached to the dining room so that one could just walk out into it. A few miniature bulbs had been grown some years back, but since lost in the pressure of running a business. Recalling these, I decided to attempt

a collection of most of the dwarf species, coupled with a similar collection of some of the better miniature hybrids. I joined the Daffodil Society, brought in as many books as I could find on daffodils, and sent off a number of orders to both wholesale and retail suppliers. In due course the bulbs were received and planted. What a mess! Most lots were diseased to some degree, and hardly one was true to name. I discovered that in most cases the bulbs were in fact collected material, gathered from the Spanish and Portuguese mountains by local people, who just dig anything. Clearly quite a task lay ahead.

The epicenter for the natural distribution of narcissus is the Iberian Peninsula: Spain and Portugal, where most of the well-known and important species are to be found. From this area bulbs have slowly spread to adjacent areas in North Africa, Morocco and Algiers, and around most of the Mediterranean coast, including the islands of Sardinia and Corsica, and into Asia Minor. Bulbs can be traced right across Asia to China, but it is believed that these were spread by travellers, for bulbs are to be found only along the line closely followed by early traders from Europe to China. Bulbs also spread slowly north to areas of France, Switzerland, and one or two found their way to the British Isles.

I began by ordering duplicate lots from as many sources as possible and followed this up by vigorous correspondence with just about everyone I knew to be interested in these bulbs. As a result I steadily widened my contacts to people in many parts of the U.S., England, Holland, Portugal, Australia, and New Zealand. From each I obtained new contacts, and so my circle rapidly increased.

In the literature two names, Douglas Blanchard and his son John, in England continually crop up. I wrote to John Blanchard and asked if I could obtain some bulbs from him. When he said that this would be possible, I decided to make a trip to England to meet him and to collect what bulbs he could spare. This trip proved to be of immense value, for not only did I receive bulbs of many unusual kinds in generous measure, but I learned some of the cultural pitfalls, and obtained a list of still more people to whom I could go. Thus, slowly over the past seven years I have gathered together quite a substantial and interesting collection of most of the wild species, plus a number of the better miniature hybrids, close to 350 different types and cultivars. I have managed to sort out to some degree bulbs which I have so that they conform to the published descriptions of the various species, and have managed to control most of the more prevalent problems and diseases to which these small bulbs may be subject. The process continues.

It is not my intention, even if it were possible, to give you a complete survey of the genus *Narcissus*, but I would like to try to introduce you to some of the more interesting wild forms, and then show you some of the hybrids, small in stature, which have been developed.

Before we go any further let me say that the correct name for all these bulbs is narcissus. Most people tend to associate the name daffodil—which is a corruption of asphodel—with the large yellow flowers having a substantial trumpet, while narcissus are the later flowering bulbs which have white petals and a neat red rimmed corona in the middle of the flower. The common name is pheasant's eye, but to be correct all are narcissus.

In the most recent botanical revue, *Flora Europea*, the genus *Narcissus* is now divided into 9 sections instead of the previous 12. Some of these are of little practical importance, being of interest only to the collector, yet I thought you might be interested in seeing just how varied the genus can be.

First comes a group which flower naturally in the fall. *Narcissus humilis* is the only member of the section Tapeianthus. The small star-like yellow flowers are produced towards the end of September. *Narcissus serotinus* in the section Serotini, another fall bloomer, is native to southern Spain—around Gibraltar and in Morocco. It flowers in October in a cool greenhouse. Another member of the fall-flowering group (in the section Jonquilleae) is *N. viridiflorus*. It has a green flower, and flowers at the same time as *N. serotinus*. This last species has little value except as an oddity.

The Tazetta or Hermione section is also very early blooming and, depending upon location, some can be in flower from mid-November onwards. They are found naturally more or less circling the Mediterranean region, and none are considered really hardy. Most of you will recognize the yellow 'Soleil d'Or' and the white 'Paper White', *N. tazetta* cultivars that are in the florists' shops from Christmas onwards. They are grown here in the north mainly as throw-away pot plants, but in the southern U.S. they are excellent for outdoor planting. Unfortunately there are almost no miniature types in this section. The same is true for the section Narcissus in which there are two or three species all very similar, but none truly miniature. The section Jonquilla has a substantial array of interesting plants, both as species and hybrids. This section used to be divided into two sub-sections. One of these was for a species whose flower stems are naturally rather tall: 9 in. or more in height and with multiple flowers on each stem. The other was for species with stems from 3 to 6 in. tall and usually only one flower on each stem.

A number of selections of the Jonquilla section have been made in the wild. The one most often seen is *N. requenii* [syn. *N. juncifolius*]. Two other species differing slightly are *N. fernandesii* and *N. henriquesii*. I think that *N. henriquesii* is perhaps the best of the group. As a matter of interest only, there is a small-flowered bulb with multiple flowers known as *N. gaditanus*. It is most difficult to flower and is of little interest except to collectors. White-flowered species in the Jonquilla section are all dwarf and come from Morocco. One of the best is *N. watieri*, with clear crisp white

flowers on 3 to 4 in. stems. *Narcissus atlanticus,* also from Morocco, is also white, although the color is not quite so crisp as *N. watieri*. It is interesting to note that all the *N. atlanticus* now in cultivation have come from one original collection of seed made sometime in the 1930's. The bulb in flower has never been found again in the wild.

Narcissus rupicola is the main dwarf yellow jonquil, and it is found in Spain. It is in effect a yellow form of *N. watieri*. *Narcissus* rupicola is quite varied and both large and small-flowered forms have been collected. One last bulb which must be mentioned in this section is *N. scaberulus*. It is diminuative, yet with 2, 3 or more flowers per stem. Although it is a jonquil it does not seem to fit into either group.

Most of you will have come across the species, *N. triandrus,* commonly known as angel's tears. Although a pan of these bulbs may show many minor differences, there are only 4 or 5 recognized botanical varieties. All of them have played a substantial part in the development of many of the most attractive hybrid bulbs we plant and enjoy in the garden. The varieties are not very satisfactory in the garden unless you have just the right place. However they grow very well under the modest protection of a cool greenhouse or frame. The species has creamy white flowers, sometimes pure white, and used to be called *N. triandrus* var. *albus*. The correct name now is *N. triandrus* var. *triandrus*. As mentioned there are other numerous minor variations, none of which are now recognized as varieties nor sub-species. *Narcissus triandrus* var. *pulchellus* has a much shorter cup or corona and should be a deep cream. Those with an even deeper cream color and longer corona, are now called *N. triandrus* var. *pallidulus*. The small-flowered intense golden yellow form known as *N. triandrus* var. *aurantiacus* is outstanding. The fourth variety is *N. triandrus* ssp. *capax,* which is found only on a small island off the coast of Brittany. It has a beautiful flower which has been used widely for breeding. However it is most difficult to obtain.

The Bulbocodii section is one of the largest and most confused of them all. These are the so-called "Hoop Petticoat" daffodils, found in many forms throughout Spain, Portugal, and Morocco. The yellow-flowering species seem to predominate in Europe, while white and cream ones are found mostly, but not exclusively, in Morocco. The most common and readily available form is *N. bulbocodium* var. *conspicuus,* with stems from 6 to 8 in. tall and each carrying one bright yellow flower of the typical hoop petticoat type. A form with a greatly enlarged corona or cup is, quite correctly called Obesus while yet another form with pale yellow flowers striped with green is *N. bulbocodium* var. *citrinus*. The standard white flowered form, found mostly in southern Spain is called *N. cantabricus,* and yet another form of this, found only in

Morocco, is called *N. cantabricus* var. *petunoides*, because the corona is quite flat and looks like a petunia. In North Africa there are duplicates of practically all the Spanish forms. They have different names, although they are clearly related. The basic type is known as *N. romieuxii*, which is slightly shorter in stem than most with clear, light-yellow flowers. A number of forms with white flowers are grouped under the one name *N. romieuxii* var. *albidus*. One form with a wide flat corona similar to *N. cantabricus* var. *petunoides* but with a clear yellow color is known as *N. bulbocodium* 'R. Julis Jane'.

Moving now to the typical trumpet type narcissus, the smallest is *N. asturiensis*, and then next in size would be *N. minor*. There are numerous forms of both of these with flower size and height varying widely. Truly white narcissus are few. There is one in this group known as *N. moschatus* and, in turn, there is a dwarf form with the most delicate drooping white flowers known as *N. moschatus* var. *alpestris*. It is most difficult to find and to grow successfully.

Finally, we come to a species, *N. cyclamineus*, which is attached to the Ajax or trumpet section. This is a delightful bulb, quite easy to grow if given the right conditions. It reproduces true from seed and has been an important parent in many of our current hybrids. This brings us to the consideration of some of the better and more readily available dwarf hybrids with a sufficiently strong constitution to be of value in any planting. Here are some of the best.

Narcissus 'Hawera' and *N.* 'April Tears' are almost identical. 'Hawera' was raised in New Zealand and 'April Tears' in England. 'Hawera' is generally available each year from any reputable garden center. It grows well, producing a number of clear yellow flowers on the top of 9 to 12 in. stems. It is a cross between a jonquil and *N. triandrus* var. *albus* and was introduced in 1938. *Narcissus* 'Tete-a-Tete' is another beauty, being in many ways almost the ideal bulb. With *N. cyclamineus* in its parentage it may have some reflexed petals at times, but it is first class for forcing, for growing in pans or for planting in the garden. 'Jetfire' is another species of the Cyclamineus Division which is much closer to *N. cyclamineus* in form but which has a rich red trumpet.

The jonquil group contains a number of first class garden plants, but hardly any are better than the two basic forms found in the wild, *N. henriquesii*, *N. fernandesii* and *N. willcommii*. Of these three *N. henriquesii* is perhaps the best. However, it is not so readily available as *N. jonquilla*, *N.* × *odorus*, or the double form with the old name 'Campernelle'.

For the real enthusiast there are a host of other hybrids not readily available except from other enthusiasts, but those detailed above should generally be available year by year from your local retailer.

JIM BLEW: Have you tried twin scaling with your bulbs?

JIM WELLS: No, I have not tried it. It is quite easy. You just slice a bulb up into 8 or 16 sections in August or September, dip in Benlate for ½ hour, place them in a plastic bag with damp peat or vermiculite, and leave them for 2 months. Little bulbs will develop on the edge of the scales and basal plate. You can plant them and they will grow.

A SURVEY OF HARDY BAMBOOS: THEIR CARE, CULTURE, AND PROPAGATION

RICHARD A. SIMON

Bluemount Nurseries, Inc.
Monkton, Maryland 21111

Bamboos belong to the Bambusoidae division of the grass family, Graminae or Poaceae. Some people have given the name "tree grass" to bamboo because of the giant size they can attain, especially in the tropics and subtopics. Since some bamboo species only reach a maximum height of 18 to 24 in. (and some varieties even less), the "tree grass" name is not appropriate for all bamboos.

There are two main divisions in the bamboos based on rhizome habit. The clump growers, or pachymorphs, have constricted rhizomes so that the plant remains in a relatively tight clump. Although the clump increases in size over the years, its increase per year is generally measured in inches rather than feet. The other group, the leptomorphs or running bamboos, spread rapidly by vigorous rhizomes which can extend out from the parent plant several feet, or more, per year. For garden purposes, the clump growers are more desirable, but, generally speaking, they are the tropical of subtropical species. On the other hand, those species that are hardy in the temperate zones are the runners. Fortunately, there are two species of pachymorphs or clump growers which are hardy and therefore valuable garden subjects, especially since they are hardy even in the Boston area. I refer to *Sinarundinaria nitida* and *S. murielae* (also known as *Thamnocalamus spathaceus*).

There are many species of hardy bamboos of the runner or leptomorphic type, ranging in height from the low growing 18 to 24 in. species to the giants of 60 ft or more. The hardiness of this group varies, but by creating microclimates and by changing our expectations, one can still grow some of these bamboos in colder areas.

Before I can explain how a bamboo grows, I need to describe and identify the plant parts. Bamboos have three main parts: the

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Before I can explain how a bamboo grows, I need to describe and identify the plant parts. Bamboos have three main parts: the

above-ground stem with branches and leaves, called culms; the underground stem-like structure called rhizomes; and the roots which are attached to the rhizomes. The culms and rhizomes have nodes and internodes. The actively growing rhizomes have a terminal bud, and at each node are one or more buds which eventually develop into culms.

In my opinion, bamboos provide us with one of the most amazing growth habits in the plant world. I will describe the growth habit of the widely known *Phyllostachys* genus to illustrate my point. Bamboo culms do not have a cambium layer or a terminal bud. This means that each culm reaches its full height and circumference within its growing period, never growing any taller or broader in succeeding years. However, in any given healthy plant, each year's new culms generally grow taller and larger in diameter than the previous year's culms. The fact that the culms develop and reach their full size in a rather short period of time, perhaps 4 to 6 weeks, is truly amazing, especially if the culms reach a height of 20, 30 or 40 ft, or more. In other words, a culm, depending on the species, will reach its full height in a matter of weeks, which means growth can be measured in terms of inches, or even feet per day, as in the case of culms which may ultimately reach 60 ft. As for the other genera and species of bamboo, the growth habits are the same, remembering that when the plant reaches its maximum height, new culms will only attain that height.

Taxonomically, bamboos are named, as are all other plants, on the basis of their flowers. A phenomenon that is unique to bamboos is that they very seldom bloom. Some species produce flowers only every 75 to 100 years. This makes it difficult for the taxonomist to accurately study and classify the bamboos. Fortunately for the botanists there are certain vegetative characteristics which can help identify the species. As for the *Phyllostachy* spp., they can be told apart relatively easily at the time of shooting. A key exists to assist the interested person to identify the various *Phyllostachys* spp. growing in the United States.

Bamboo species vary in hardiness. There is little literature listing precise hardiness of the many species of temperate bamboos. Some species not hardy in colder regions may still survive and even thrive if planted in a modified microclimate. Some species may survive even though the current year's culm growth is killed to the ground. The key for survival in these situations is the protection of the rhizome against winter kill. If enough mulch is added on top of the rhizomes, the plant can persist. Bamboos hardy at Bluemount Nurseries are listed in Table 1.

The propagation methods of bamboo are rather limited. The three primary methods are: by bare-root rhizome sections, by removing existing culm growth with a ball of soil to include a part of the rhizome and roots, or by dividing rhizomes from pot-grown

Table 1. List of bamboos hardy at Bluemount Nurseries, listed according to maximum height attained at Bluemount

Species	Comments	Size (ft.)
Phyllostachys nuda	hardiest	30 to 35
P. dulcis	hardiest	30 to 35
P. bissetii		25
P. decora		20
P. aureosulcata		15
P. aurea	dies to ground in severe winter	8
P. nigra	dies to ground in severe winter	8
Semiarundinaria fastuosa	slow grower, very hardy, seldom shows leaf burn	15 to 20
Pseudosasa japonica	dies to ground in severe winter	15 to 20
Sinarundinaria nitida		8 to 10
Thamnocalamus spathaceus	clump grower very hardy	8 to 10
Sasa palmata		4 to 6
Shibatea kumasasa		4
Arundinaria viridi striata	very hardy, deciduous	4 to 4
Sasa veitchii	very hardy	2
Sasa pygmaea		2
Arundinaria variegata		2

plants. At Bluemount Nurseries, we have tried side-branch cuttings under mist and layering with no success. Some researchers are experimenting with tissue culture and cuttings, but report limited success.

In order to propagate bamboo by rhizome sections, it is necessary to carefully dig the rhizomes in late winter or early spring and cut the rhizomes to include a 2-node section. The rhizome section must not be allowed to dry out, even for a short period. We plunge the rhizomes immediately in a tub of muddy water and pot or replant the sections as soon as possible. We actually have greater success in digging B&B for transplanting than we have in planting rhizome sections. We dig any time of the year, except during the 4 to 6 week period when the bamboo is shooting, which for most species is in late April or early May at Bluemount Nurseries. Once dug, the plants should be hardened off. We have dug successfully in mid-summer by keeping the newly-dug plants in the shade and syringing the foliage several times a day for several days. We do not dig bamboo during shooting because the new shoots (culms) are very brittle and can easily be broken off.

Dividing pot-grown bamboo is relatively simple and very successful. The culms are separated with rhizomes and roots attached, repotted immediately, and protected until established.

Bamboo requires little care in the garden, once established. I

recommend spring or summer planting rather than fall planting so that the rhizomes or culms can be established before winter. Usual horticultural practices generally result in a good survival rate. Bamboo tolerates a deep mulch and generally do not require addi- fertilizer once established.

A word of caution. The running bamboos are very vigorous and can spread quickly into areas where they may not be welcome. It is, therefore, best to contain these types. My recommendation is to bury fiber glass panels at least 30 in. for the taller growing types and 8 in. for the shorter growing varieties.

USING SPUNBONDED FABRICS FOR COLD PROTECTION

RICHARD E. BIR

MHCREC, 2016 Fanning Bridge Road
Fletcher, North Carolina 28732

INTRODUCTION

Plastics and textiles have played an increasingly important role in the continuing search for better ways to grow nursery crops. Continuous films of clear plastic have replaced glass throughout the industry. Woven polymer shadecloth provides reduced heat and light to sensitive crops, is easier to handle and has become less expensive than wooden lath. Milky white plastics have become an integral part of winter protection for container nurseries. Insulating plastic foams and laminates help nurseries overwinter more valuable or delicate stock.

Today, we are often pumping water through plastic pipe and nozzles onto plants in plastic pots on a plastic groundcover with plastic protection between the plant and the sky. Polyethylene, polypropylene, polystyrene, etc. have become familiar terms during the polymer revolution that has captured us in the past 20 years. This rapid change has occurred because the nurseries must use technology that will perform required tasks as well as or better than existing technology, at the same or less cost while fitting into existing nursery practices. It was all of these criteria that led us to investigate ways that spunbonded fabrics might be used in North Carolina mountain nurseries.

Spunbonded fabrics. *Spunbonded fabrics differ from other* porous polymers in that they are not woven into a regular, uniform pattern like shadecloth. Spunbonding is a continuous process in which a polymer, or several polymers, such as polyester, poly-

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Spunbonded fabrics. *Spunbonded fabrics differ from other* porous polymers in that they are not woven into a regular, uniform pattern like shadecloth. Spunbonding is a continuous process in which a polymer, or several polymers, such as polyester, poly-

propylene, or others is fed into an extruder. As it flows from the extruder it is forced through a device with tiny holes. After cooling, the continuous filaments are laid down on a moving belt. While being laid down the desired orientation is achieved, then the fabric is bonded using combinations of heat, pressure, and chemicals.

Because of this process, every time fibers cross, they should be bonded together. This limits the unravelling and stretch characteristics found in some woven fabrics. Holes are built into the fabric. These holes permit the passage of water and gasses. This allows plants beneath a spunbonded fabric to have air exchange and permits irrigation without removing the fabric cover.

Work on vegetables, tobacco, turf, and particularly that reported at the 1984 National Agricultural Plastics Congress, stimulated us into looking for ways that spunbonded fabrics might be used in North Carolina mountain nurseries.

Spring frost protection of 2 to 5°F, with about 7°F fall frost protection was claimed in New Hampshire. This was difficult to accept from a hole-filled 5.5 mil thick fabric. Illinois data showed that soil moisture averaged 3% higher following rainfall or irrigation under a Reemay cover. Early season growth of tobacco seedlings, turf, earliness and increased yields of vegetables, plus reduced insect damage, all intrigued us so we set up a series of on-farm tests to see if spunbonded fabrics might have a use in North Carolina mountain nurseries.

Conifer seedling protection. *One year old (1–0) conifer* seedlings must be mulched during North Carolina mountain winters to prevent heaving. Widely fluctuating winter temperatures create hoar frost which can lift small seedlings out of growing beds. When the ice that lifted seedlings melts, roots are exposed to the air. Roots then dry out leading to seedling death. To prevent this, standard practice has been to mulch beds of 1–0 conifer seedlings with straw or locally obtained hardwood leaves in late November or early December, after seedlings have been exposed to frosty nights for 4 to 6 weeks. Beds are center crowned by stacking the mulch deeper in the middle. This acts like a thatched roof, shedding much winter rain. Mulch is secured against winter winds with either shadecloth or pea netting. Beds are usually uncovered from mid-March to mid-April, about 6 weeks before the average last frost date. Mulch is removed very carefully to avoid pulling up small seedlings.

Problems we have encountered using organic mulches include: 1) high labor cost, 2) poor moisture control, 3) introduction of pests, 4) harboring rodents, and 5) lack of light for 3½ to 4 months. In 1985 we estimated that the cost of using organic mulches was about $16 per 400 sq ft bed.

In December 1984, we set up a nursery test at 3400 ft elevation to determine whether spunbonded fabrics would provide equivalent protection to organic mulch. Seedlings (1–0) of eastern hemlock

(*Tsuga canadensis*), eastern white pine (*Pinus strobus*), and Fraser fir (*Abies fraseri*) were used as test plants. Plant population in four, 1 sq ft plots in each 100 sq ft mulch test section was determined on December 5, 1984. Each section was then covered with either organic mulch (OM), a single layer of Kimberly-Clark spunbonded polypropylene (KC6), or a single (RM1) or a double (RM2) layer of DuPont Reemay 2006 spunbonded polyester.

Nursery air temperature and air temperature under the mulch were measured using Max-Min thermometers and recorded weekly. Nursery soil temperatures and soil temperatures under the mulch were also recorded weekly from soil thermometers reading at depths of 2 or 4 in. below the soil surface.

Mulch was removed on March 19, 1985. Plant population was determined immediately and any visual differences noted. Plant height was measured on June 20, August 13 and October 1, 1985. No plant heaving or death occurred in test plots due to mulch treatments. Species response, however, was quite variable.

Fraser fir: No visual differences existed for Fraser fir at any time in the test. Plants in the KC6 plots were significantly shorter (Table 1). However, a difference of ½ inch may not be important to a grower.

Table 1. 2–0 Fraser fir height (in.) on June 20, 1985 following winter protection under selected mulches.

Mulch	Height (in.)
OM	2.5 a*
KC6	2.0 b
RM1	2.5 a
RM2	2.8 a

*R_{p05} Duncan's New Multiple Range Test

Eastern white pine. Pine foliage under both Reemay treatments was uniformly blue-green on March 19. Plants under the organic mulch were uniformly mottled brown and yellow, with many totally dead needles. Plants under KC6 ranged from blue-green to brown. The patches of discolored seedlings seemed to correspond to thicker and thinner spots in the KC6 covering. This suggests that the positive response was due either to increased light penetration or better gas exchange during the 15 week test period.

Seedlings that had been protected under a single layer of Reemay were significantly taller (Table 2) than those that had been under an organic mulch when measured on June 19. By the time they had finished height growth for the 1985 season (August 13, 1985), no significant height difference existed between plants in the organic and KC6 mulch treatments, while plants in both Reemay treatments were significantly taller.

Table 2. 1–0 Eastern white pine seedling height (in.) following winter protection under selected mulches.

Mulch	DATE	
	June 20, 1985	August 13, 1985
OM	3.2 b*	4.5 b
KC6	3.5 ab	4.6 b
RM1	4.4 a	6.4 a
RM2	4.3 ab	6.8 a

*R_{p05} Duncan's New Multiple Range Test

Eastern hemlock. Hemlocks under either Reemay treatment were yellow-green when uncovered. This color change occurred during the last week under mulch. Within two weeks of normal spring fertilization, hemlock needles were again a normal deep green color.

This color change cannot be accounted for by heat build-up under Reemay alone (Table 3). However, a temperature fluctuation of 72°F under RM1 and 63°F under RM2 may be a contributing factor. The color change reported is characteristic of the response when sunlight shines on frost-covered hemlock needles in the spring. Since Reemay is translucent (75% light transmitted), a "frost burn" under the Reemay mulch may have caused the color change. This experiment was repeated the following winter, removing Reemay mulch in successive 100 ft. sections during March 1986 to determine whether removing the mulch earlier could prevent discoloration. No discoloration occurred regardless of when the mulch was removed in 1986.

Table 3. Air temperature (°F)* under selected mulches covering eastern hemlock.

Interval	Mulches					
	RM1		RM2		OM	
	Max	Min	Max	Min	Max	Min
2/26–3/5	66	20	68	23	66	27
3/6–3/12	80	20	72	22	68	18
3/13–3/19	86	14	79	16	81	19

*Average of three thermometers

While no visual difference was apparent on June 20, 1985, hemlocks that were discolored under Reemay in March were significantly shorter. By October 1, 1985, no significant height difference existed (Table 4).

Seedling conifer conclusions. Reemay and KC6 were as effective as organic mulches in protecting 1–0 eastern hemlock, eastern white pine, and Fraser fir seedlings from winter damage due to soil heaving. With white pines, an additional benefit in both appearance and growth occurred with either a single or double layer of Reemay 2006 mulch.

Cost factors favor using a single layer of Reemay mulch. The cost of covering a 400 sq ft bed with a single layer of Reemay was estimated at $11.50 in 1985. This was $4.50 per bed less than with an organic mulch. A tear strength of 68% was retained by a single layer of Reemay after 15 weeks exposure in this test. This suggests that the Reemay might be safely reused a second season, thus reducing costs even further.

Table 4. Eastern hemlock seedling (2–0) height (in.) following winter protection under selected mulches.

	DATE	
Mulch	June 20, 1985	October 1, 1985
OM	5.8 a*	13.5 a
KC6	5.4 ab	12.9 a
RM1	4.9 b	12.8 a
RM2	5.0 b	13.1 a

*R_{p05} Duncan's New Multiple Range Test

Temperature response. In Table 5 air and soil temperatures are shown for the coldest, second coldest, and warmest weeks of the 1984–85 winter. During both the coldest and second coldest weeks of the winter a single layer of Reemay provided superior cold protection to the organic mulch. The difference in protection of over 20°F during the week of January 15, 1985, and only 7°F during the next week is a reflection of how Reemay works.

During the week of January 15 there was no snow cover so light could penetrate the Reemay, warming the soil underneath. During the following week, a light snow blanketed the test preventing most light from reaching the soil with less heat accumulated under the mulch.

Table 5. 1985 air and soil temperatures (°F) with selected mulches of 1–0 conifer seedlings.

	Mulches			
Interval	None	OM	RM1	RM2
1/15–1/22/85				
Max	50	57	49	50
Min	−20	3	8	20
2 in.	30	31	31	44
4 in.	34	31	32	38
1/22–1/30/85				
Max	51	50	45	48
Min	−2	2	5	6
2 in.	32	31	32	44
4 in.	31	32	32	36
3/12–3/19/85				
Max	80	78	86	79
Min	10	18	14	23
2 in.	57	49	53	49
4 in.	54	47	60	56

Rarely a winter week passes in the North Carolina mountains without temperatures rising above freezing. As a result, even though soil remained frozen for over a month, no temperature below 30°F was recorded at 2 or 4 inches deep.

Container-grown ericaceous seedling protection. To protect container-grown ericaceous plants from cold, roots must not reach temperatures as low as air temperatures. The flow of drying and cooling air around plants must be restricted. Using the temperatures shown in Table 5 and the moisture retention reported in Illinois as inspiration, we set up a test with a producer of flat and pot-grown native ericaceous liners.

All available unheated greenhouse space for winter protection was filled but, because of expansion, this same space would need to be used and heated by February for the next crop. The expense of building winter protection structures on his terraced mountainside was an option this small-scale grower did not relish.

In an attempt to find an alternative, flats of seedling ericaceous liners 1 to 4 in. tall were thoroughly watered, set on crushed rock surfaced terraces and covered with a single layer of Reemay. We hoped to prevent heaving of the smaller seedlings, plus avoiding root temperatures cold enough to kill the seedlings (estimated at below 10°F).

Plants were uncovered in mid-March. No breakage had occurred despite a 22 in. February snowfall. No rodent damage existed as it had under organic mulches in another test. Most important, all the seedlings lived and resumed normal growth slightly earlier than those in unheated white copolymer film covered houses.

Container-grown herbaceous perennials. A mail-order nurseryman was dissatisfied with the current system for protecting his herbaceous perennial crop of mostly 2¼ in. to quart container-grown plants of diverse species. His system was to cover production houses with 6 mil white copolymer film. When the coldest temperatures threatened, he placed Microfoam over plants that experience had shown were most likely to be injured.

While the Microfoam performed excellently, the variable weather in the Asheville area, plus pulling orders for shipping, required moving the Microfoam frequently. He felt the labor involved, expense, and storage of Microfoam were negative factors. Also, maintaining nearly 100% humidity and temperatures near freezing around the crowns of some crops made him uneasy.

In 1984–5, he experimented with Reemay. The Reemay was folded along side flats of pots on the floor of his crushed rock surfaced white film covered greenhouse. When cold weather was forecast, one or two people easily covered plants in a few minutes with this light weight material (67 in. wide × 100 ft. long section weighs 2.3 lbs.). In 1985–86, all plants were protected with Reemay. The ease with which it can be handled, its relatively low cost, plus

"breathing" to allow leaves and crowns to dry were considered positive points.

DISCUSSION

During spring, heat can build rapidly under Reemay and KC6 and damage newly germinated sugar maple seedlings if covers are left on top of seedlings when air temperatures exceeded 80°F. In another test we had beds of Norway maples covered with KC6 or Reemay all winter. The seeds never germinated but were completely viable. Apparently, the heat building up in the soil surface almost daily prevented proper stratification.

We also tried using Reemay as a 25% summer shade. While 68% of tear strength remained after 15 weeks exposure in winter, it breaks down rapidly under August sun and wind, lasting no longer than 3 to 4 weeks before tearing. Once these fabrics are lifted from the soil surface they very effectively catch the wind.

CONCLUSIONS

Spunbonded fabrics show nursery potential in a variety of situations. Where sunlight can penetrate and build heat under a fabric mulch, a few degrees of winter protection can be expected. In Florida, tender crops have been protected from frost and cold winds simply by draping Reemay on top of foliage.

In North Carolina these fabrics hold potential as an economical mulch over hardy conifer seedlings. They may be used to protect very hardy container-grown seedling ericaceous plants as well. The limited degree of cold protection provided means growers should be cautious when trying to protect more tender plants or in a more severe climate.

PRESENT LIMITATIONS AND FUTURE PROSPECTS FOR COMMERCIAL MICROPROPAGATION OF SMALL FRUITS

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Micropropagation has had a significant impact on the commercial propagation of several small fruit crops, especially bramble fruits. Tissue culture is commercially viable under certain conditions, primarily because these crops are relatively slow and labor intensive to multiply by conventional techniques, and because of the demand for virus indexed registered stock. Red raspberry, for example, is difficult to root from cuttings, and hence is conventionally propagated mainly by division of canes arising from root suckers. Typically, a multiplication rate ranging from about 4 to 1 per year is achieved with stock infected with common viruses. At Congdon and Weller Nurseries, however, multiplication rates of about 10 to 1 per year are achieved from division-propagated stock largely because of a virus index registration program which has been in place since 1964 (11). These relatively low rates of multiplication combined with stringent cultural requirements required for participation in the New York State Virus Tested Plant Material Program made conventional propagation particularly daunting. Virus indexed nuclear stock was kept free of tobacco streak virus and mosaic viruses by growing it in screen houses to exclude aphids and leaf hoppers which are the vectors of these viruses. Foundation I stock was propagated from nuclear stock by division and replanted. Although no longer screened, Foundation stock was still protected from reinfection by eliminating native brambles within a 1000 foot radius and a rigorous pesticide spray program. Control of the digger nematode (*Xiphinema americanum*) which transmits tomato ringspot virus (the cause of crumble berry in brambles) required the additional considerable expense of soil fumigation before planting. In the past several years, micropropagation has completely eliminated the use of screen houses for red raspberries and reduced the amount of time required to produce 30,000 plants of a newly released cultivar from 5 or 6 years to about 2 years. Under these circumstances the advantages of micropropagation become readily apparent. Furthermore, field performance of brambles propagated through tissue culture may surpass that of convention-

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ally propagated material. Tissue culture propagated thornless blackberries, for example, exhibited greater vegetative vigor and uniformity than tip layer propagated material (9).

Considering these obvious advantages of small fruit micropropagation and the fact that relatively straightforward techniques are available for each of the major crops, the conclusions of a recent survey conducted by Swartz and Lindstrom (8) are somewhat surprising. They reported that only approximately 13% of bramble fruit nursery stock in the U.S. is propagated via tissue culture. Micropropagation accounts for about 5% of blueberry nursery stock and less than 1% in the case of grape and strawberry. The remainder of this review will consider some of the economic and cultural factors which limit the commercialization of small fruit micropropagation and discuss some research currently underway directed towards overcoming some of these limitations.

Simple economics is the most important impediment to increased commercial micropropagation of both strawberries and bramble fruits. The selling price is about 30 to 50% higher for micropropagated brambles and 4 to 7 times higher for micropropagated strawberries than their conventionally propagated counterparts (8). The existing demand for micropropagated red raspberries (13% of the market) despite their relatively high cost stems largely from the fact that they are produced and marketed as virus-indexed, registered and, as such, they can be counted on to perform better than nonregistered stock.

Despite whatever horticultural (noneconomic) advantages which might accrue from the planting of tissue culture propagated small fruits, there is little doubt that demand would grow significantly if the costs of micropropagation were to decrease. One of the most significant contributors to the relatively high cost of micropropagated small fruits is the considerable amount of skilled hand labor involved. Several cost analyses of commercial micropropagation have consistently identified labor as the major expenditure. Labor costs as a fraction of the total cost of propagation range from low of 39% for chrysanthemum (2), 67% for foliage plants (6), and as much as 76% for broccoli (1). Recently, Borgman (3), working in the principal author's laboratory, has completed a detailed microcomputer-based analysis of the costs and potential profitability for commercial scale micropropagation of red raspberry. Net present value analysis was used to correct for the effect of inflation on fixed and variable costs incurred over a 10 year period. Despite the use of a variety of labor and time saving devices available to the modern tissue culture lab including an autoclave, multiple transfer hoods, automatic dishwasher, and media dispenser, labor was still the major cost of production, accounting for about 50% of the total expense. Axillary shoot culture, the technique used in the micropropagation of small fruits and practically all other

commercially micropropagated crops, is inherently labor intensive. The technique involves the cytokinin-stimulated proliferation of basal axillary and/or adventitious shoots from a single shoot tip explant (stage II). Typically, during this most labor intensive stage, a technician, working under aseptic conditions, with scalpel and forceps, must meticulously subdivide a rosette consisting of several shoots, and transfer each individual shoot to fresh medium. For red raspberry, multiplication rates are on the order of 4 to 1 over a 4 to 6 week period. Thus, many successive subcultures (5 or more), (and hence much time and labor) are commonly required to generate commercial numbers of plantlets (thousands to hundreds of thousands) from several initial (stage I) explants. The transfer of axillary shoots does not lend itself easily to automation because the delicate microshoots are easily damaged and each must be precisely oriented in the new medium. When sufficient numbers of shoots are available they are rooted, either in vitro (Stage III) by transfer to an auxin-containing medium, or ex vitro (Stage IV) by removal from culture to a high humidity greenhouse where they are treated as microcuttings. With small fruits, rooting is mostly ex vitro, because high rooting percentages are achieved, and because it is less labor intensive than in vitro rooting.

One potentially labor saving approach to micropropagation being investigated in the principal author's laboratory is root organ culture. This would involve culturing root rather than shoot tissue during stage II. After the desired level of root multiplication is achieved, plantlet regeneration would be accomplished by inducing adventitious bud formation on the root cultures (Stage III). The savings in labor would arise from the fact that roots can be subdivided (chopped up) without regard for the need to keep buds and leaves intact or the need to accurately place the explant on the new medium as is so time consuming in subculturing of shoots. If bud initiation and shoot growth could be delayed until the last passage in culture it would be unnecessary to subdivide shoots at all.

Red raspberry is particularly well suited for investigating the potential usefulness of this approach to micropropagation, because of it's natural tendency to sucker. Suckering begins with the formation of adventitious shoot buds on the roots of a plant growing in soil. This is physiologically quite similar to the induction of adventitious buds on root organ cultures in vitro, and suggests that root organ culture followed by plantlet regeneration (in vitro suckering) might be successfully exploited for the sake of micropropagation. In our laboratory we have succeeded in culturing roots of several cultivars of red raspberry including 'Titan', 'Heritage', 'Sentry', and 'Latham' (4). Root explants were severed from in vitro rooted stage III shoot cultures and placed in liquid Anderson's medium. In the presence of the auxin IBA they grew mainly by initiation and elongation of latèral roots. Figure 1 shows the effect of IBA concentra-

tion on lateral root formation. For newly initiated root cultures there was a sharp optimum at 0.5 mg/L, but root cultures which had been subdivided and transferred through 5 passages had a significantly lower optimum IBA concentration (0.1 mg/L), suggesting that auxin habituation may have occurred. Root cultures also grew readily on agar or gelrite solidified media. Bud regeneration followed by shoot development has been achieved on both liquid and solidified culture medium, but the frequency of bud initiation has been low. Bud regeneration frequency was higher from 'Heritage' than from 'Titan' root cultures. This was as expected because the former also has the greater tendency to sucker naturally. The principal focus of the research at the present time is to determine the optimal hormonal and/or other conditions necessary for shoot bud initiation, and eventually to adapt the technique to commercial scale micropropagation.

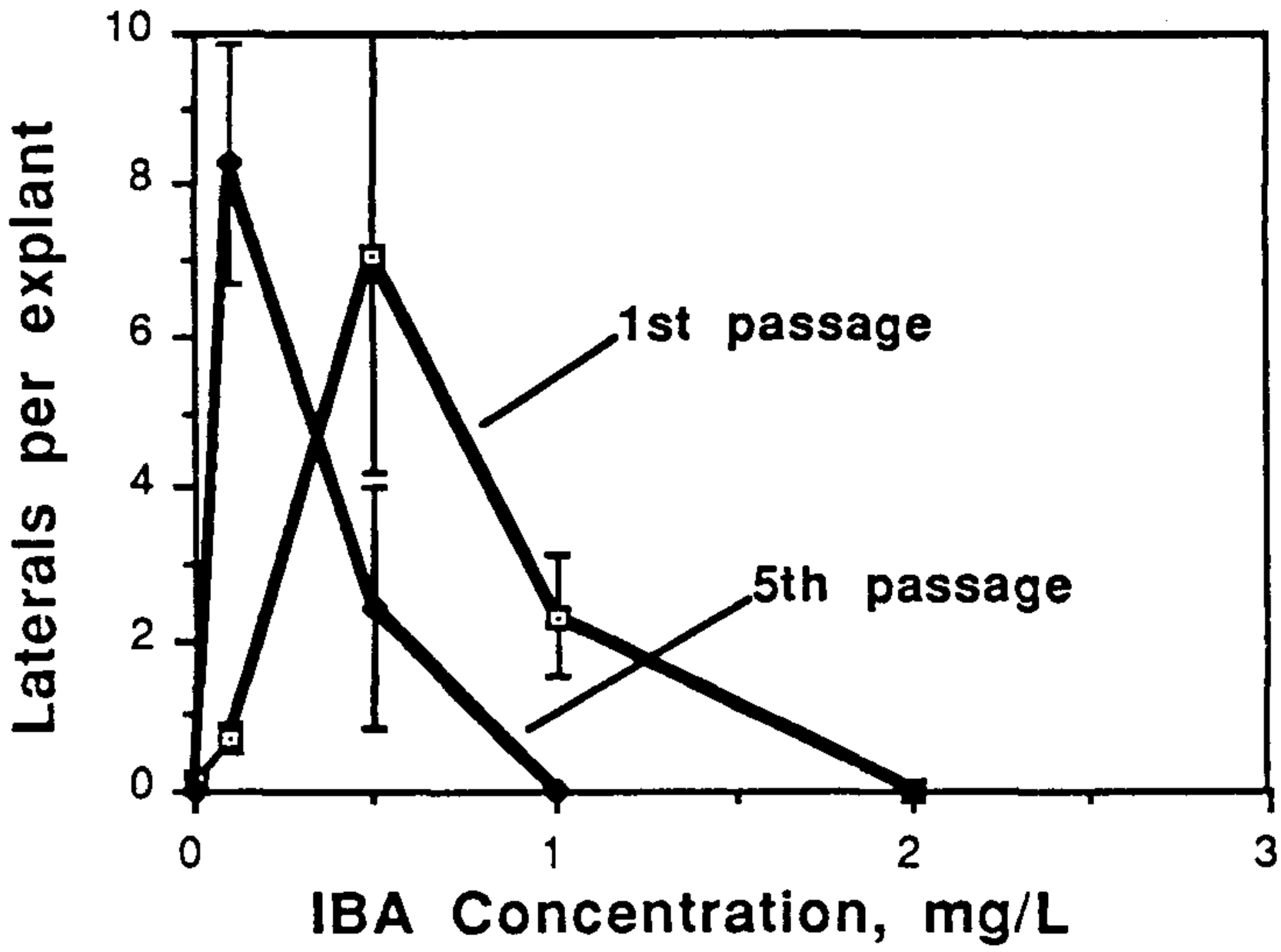

Figure 1. Effect of IBA concentration on lateral root formation on root organ culture of 'Titan' red raspberry.

In addition to economic factors which limit the commercialization of small fruit micropropagation, there are biological limitations as well. Included in this category are concerns about the occurrence of off-type plants resulting either from genetic mutations or from more or less transient phenotypic (epigenetic) changes. For example, increased thorniness has been observed in micropropagated gooseberry (10). Another related concern is increased susceptibility to certain diseases and biocides in plants which have been micropropagated. After out-planting, tissue culture propagated strawberries have been shown to have increase susceptibility

to the pathogens which cause red stele and Verticillium wilt (7). It has been observed at Congdon and Weller nurseries that field plantings of micropropagated brambles were injured by lower-than-recommended rates of the herbicide Princep (Simizine), during the first growing season, but unaffected by the maximum recommended rate during the second growing season. Recently, one of us (JCN in collaboration with M. Pritts) has conducted greenhouse and field experiments at Cornell University which confirm these observations. Micropropagated and conventionally propagated (tip layered) 'Royalty' purple raspberry plants were treated after outplanting with recommended rates of several herbicides registered for this crop. Table 1 shows that growth (dry weight) of micropropagated, but not of conventionally propagated (tip layered), plants was significantly reduced by both Princep and Surflan, compared to untreated controls. These and similar observations concerning enhanced disease (7) and biocide (5) susceptibility in micropropagated plants suggests that more research in need to develop alternative pest and weed control practices.

Table 1. Effect of three herbicides on growth of micropropagated and conventionally propagated 'Royalty' purple raspberry.

		Growth as percent of control	
Herbicide	Rate, # a.i./A	Micropropagated	Tip-layered
Control	0	100	100
Simizine (Princep)	1	43*	74
Oryzalin (Surflan)	2	57*	69
Diphenamide (Enide)	6	65	70

Commercial micropropagation of small fruits is an excellent example of the impact of biotechnology on horticultural production. Further research directed toward developing more efficient and cost effective methods should result in increased use of this already important form of propagation.

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Tuesday Afternoon, December 9, 1986

The afternoon session was convened at 2:00 p.m. with Carla Patore serving as moderator.

MODIFIED SIDE GRAFT FOR DECIDUOUS TREES

JOERG LEISS

Living Carpet Reg.
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Our basic approach to outdoor grafting of deciduous trees had always been coupling or triangling. When the scarcity of good, capable grafters to make intricate triangle grafts became a problem, we decided to try modified side grafting. We felt that this procedure would solve two of our problems; the need for experienced and skilled grafters, and the poor "takes" that we encountered with various species. This resulted in the loss of the full standard. When only a portion of the stem is lost, the tree is made less uniform and not as readily saleable.

To overcome both of these problems we decided to see if side grafting, as we were using in evergreen grafting, might work. We were grafting around 30,000 evergreens at that time, had plenty of experienced help, and time to train more, as grafting is done during our slacktime—winter.

Let me describe to you the procedure using *Morus alba* 'Pendula', which is grafted onto *M. alba* or *M. alba* var. *tatarica* as

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Let me describe to you the procedure using *Morus alba* 'Pendula', which is grafted onto *M. alba* or *M. alba* var. *tatarica* as

an example. When top grafting it is important that understock and scion heal as fast as possible, yet does not interfere with other more urgent tasks in the spring.

Scionwood is gathered early in the season before there is any active growth. The beginning of April is a good time in our area (Mississauga, Ontario). Scionwood is kept moist and refrigerated at −1°C until needed. The stems of the understock have been cleaned up the previous fall to 20 cm above the grafting height of 1.8 m and the top branches reduced to between 20 and 30 cm.

When we actually see sap exuding from a cut we commence grafting. The scionwood is taken from storage and cut into two bud sections. This length is sufficient as seldom will more than two buds sprout. Longer scionwood also dries out and reduces "take". It is important that only well-ripened, one-year wood is used.

A long sloping cut, placing the knife at an angle of approximately 30°, is made on the scion with a bud opposite. The scion is finished by cutting the lower portion on the other side of the first cut at a fairly blunt, short 60° angle. The understock is cut from above at a very shallow angle downward, best from where a branch has been removed. This cut should be slightly longer than the long cut on the scion and the resulting flap is trimmed to the length of the shorter cut on the scion. What we are doing essentially is to use a woody scion in the manner of chip budding.

The scion is placed into this cut making sure that all cut surfaces match and is then tied and waxed. Great care should be given to proper waxing, especially the area where stem and scion meet. When the scion starts to sprout after 4 to 5 weeks the top is cutoff and the wound dressed. Regrafting can be carried out in the same season for any scions that have obviously not taken, or the tree can be left to be redone the following year, by letting the top grow on. Besides *Morus* we also use this procedure for *Euonymus* standards and I can recommend modified grafting for other difficult subjects.

We found this procedure quite workable and, in addition to not losing a standard that had taken 3 to 5 years to grow, we added the benefit of a growing top. This draws sap to and past the graft, resulting in better takes and not spoiling expensive understocks.

VOICE: Does "bleeding" inhibit the formation of the graft union?

JOERG LEISS: No, in my opinion it does not. In fact, if they do not "bleed" it is too early to graft.

NEW ADVANCES IN BENCH GRAFTING

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Bench grafting of scions on bare root understocks has long been a mainstay of the production of wine grapes and fruit trees, particularly fruiting apples. It is a slower and more expensive process than budding the same trees on understocks already established in the field. Nevertheless it has several advantages over field budding. It is done at a traditionally "slow" time of the year for northern nurseries when there is little to do outside in the field and extra workers are available. Plants which sprout vigorously from the understocks, like *Hamamelis* and *Corylus*, sucker far less from deeply planted bench grafts than from pot grafts. Similarly budded trees like crab apples and Japanese cherries, which sucker readily from the understock, give far less trouble from grafts because the graft union is more deeply buried. Lilacs and other plants which are grafted on nurse roots with the intention that the scions callus and then put out their own roots produce superior and more permanent plants than when they are budded on the same understocks. In the production of special double-budded or double-grafted fruit trees for orchard production, bench grafting can save a year's production time over trees double-budded in the field.

One criticism of bench-grafted trees is that the first year's growth is noticeably shorter and smaller than that of a budded tree. In the case of orchard trees and small flowering trees like crab apples, where a long smooth stem is not essential, a grafted tree compares favorably with a budded tree in the total production time required. The budded tree requires a season's growth in the field to reach budding size, whereas a bench-grafted tree grows to a respectable size that first season. In the end, after the second season's growth, the bench-grafted tree is saleable as a small branched tree whereas the budded tree has merely produced a lightly branched or unbranched whip. Thus for producing trees for mail order sales or for potting for garden center sales, a bench-grafted tree has distinct advantages in producing a nicely branched medium sized tree much more acceptable to the customer than a mere whip, no matter how vigorous it may be.

In the case of ornamental trees and shrubs, bench grafting has further advantages because it is possible to bench graft many species which are extremely difficult or even virtually impossible to bud. Here, too, the reduction in suckering can be very advantageous in those species which sprout easily from the understock. Grafted wisterias sprout easily from the root crown and it takes a

real expert to recognize the suckers. Ornamental clones of *Corylus avellana* and *Hamamelis* selections are extremely difficult to produce from softwood cuttings. Bench grafts planted with the union well below the surface of the soil sucker much less than pot-grafted plants. While the skilled nurseryman can easily recognize and remove suckers in these species, the home gardener usually does not, and the result is a thicket of sprouts from the rootstocks which crowd out the desired cultivar scion.

All cultivars of woody plants which can be propagated by bench grafting can also be propagated by grafting on potted understock. However, pot grafting is the most expensive and slowest of all forms of propagation. First of all, the understocks must be potted up in durable pots and grown for a season to produce a well-established plant for grafting. Such an understock is already an expensive plant in comparison with a bare root seedling. Handling a potted plant and grafting it is much slower than handling a seedling. If whip and tongue bench grafts are made, the skilled grafter can pass them to a less skilled tier which greatly increases the grafter's daily output. Pot grafts have to be tied by the grafter himself. In the case of really difficult subjects like grafted pines, spruces, firs, true cedars, and other conifers, pot grafting is essential for successful stands, but for many other deciduous plants time and money can be saved by bench grafting.

Many beginning propagators have tried bench grafting with very disappointing results. In almost every case, these poor results or total failures are caused by not permitting the grafts to callus prior to planting out or potting up the grafts in containers. The bare root grafts should be heeled-in in boxes of peat deep enough so that the graft union can be covered. Some apple grafters use boxes of aged sawdust successfully, but peat does seem to have some advantageous fungistatic properties. The boxes of grafts should be placed in a cool but not freezing greenhouse and examined carefully once a week to see how the callusing is progressing. The cool temperatures are necessary to prevent sprouting of the scions into active growth before the graft union has sufficiently callused. Crabapples and cherries are particularly liable to sprout prematurely, while ginkgos, wisterias, parrotias, and, hamamelises are slow. The boxes of grafts should be watered whenever the surface of the peat dries noticeably. However, only a light sprinkling of water should be given. Heavy watering or intermittent mist can cause the lower peat or sawdust in the boxes to become watersoaked and the understock roots will rot. The speed of callusing and the frequency of watering vary from year to year depending upon the late winter temperatures and the amount of sunshine. Like so many other forms of propagation, successfully handling bench grafts is an art more than an exact science, and it is not readily subject to an exact, mechanical regime. The big variable factor is the weather. The time

required for successful callusing is much shorter if the weather is bright and warm than if it is cloudy and cold, even though the grafts are stored in a cool greenhouse. In some nurseries where bench grafting is an important process, the boxes of grafts are stored in a greenhouse with a heated floor. This kind of facility permits rapid callusing of the graft unions while the air above the grafts can be kept quite cold to retard sprouting of the scions. Such a greenhouse with a heated concrete floor is an excellent facility for mist propagation of difficult-to-root softwood cuttings during the rest of the year after the grafts have been put in storage, and it can be put to almost constant use in propagation.

Once the grafts have callused and the scions are showing signs of bud break the boxes of grafts should be removed from the callusing house and put in cold storage. This move has the effect of stopping all further scion growth until the grafts are planted out in the field or potted up in containers. The darkness of cold storage has no adverse effect upon the condition of the grafts during storage. The temperature during this holding period should be cold, between 33 and 36°F if possible. Cold temperature stops the growth of fungi which could otherwise attack the graft unions or the rootstocks. The medium covering the roots and the graft unions should be moist but not wet when the boxes are put into cold storage. Normally, no further watering is necessary until planting time.

A number of different materials have been used successfully for tying bench grafts. The oldest method was to tie the graft with string and then paint the finished graft union with grafting wax. Millions of successful grafts have been made with this method, but it is especially slow and cumbersome, requiring a heated pot of wax and an extra worker. The wax temperature is critical. If it is too hot it will penetrate the cuts and inhibit or prevent callusing. If it is too cold, it will not seal well. In the case of nurse grafts, it will inhibit rooting from the scion.

A second method is to use special grafting adhesive tape. This is much quicker than using string and waxing, but it does not give as tightly tied a union as does string. It inhibits scion rooting if this is desired, but the progress of callusing is more difficult to observe.

A third method is to tie the union with grafting string which has been previously soaked on the spool with melted grafting wax. This waxed string is quick to apply and does not need to be tied at the end of the graft as does unwaxed string. It lasts long enough to plant or pot the graft without dislodging the graft union and then rots as the graft begins to grow and the ground or the planting medium warms up. Care must be used to wrap the graft evenly and not too thickly with the string. A wad of wraps in one place will not rot easily in the ground and the resulting constriction can girdle the graft and kill the scion.

A new material which is especially useful for difficult subjects

is to use strips of 12 × 1 in. thin clear polyethylene tape, 1½ mil in thickness. It is perfect for grafts in which the union will be above the ground. It is not good for grafts with buried unions because polyethylene does not rot in the ground. The union must be tied with a rubber budding strip prior to wrapping with the poly strip because the latter is too weak to make a tight union. The poly holds in the moisture produced by the cut surfaces of the graft, while permitting normal gas exchanges. This method is too slow for mass produced grafts like fruiting apples and ornamental crabapples and cherries. It is very valuable for topworked specialty grafts like weeping elms, weeping mulberry, and other ornamentals and it is excellent for deciduous grafts on potted understocks such as oak, beech, *Hamamelis, Aesculus,* and *Parrotia.* The old method of treating such grafts was to plunge the unions in beds of peat or to lay them on peat under double glass, both being slow and cumbersome. Using the poly strips, such grafts can be set up on the open greenhouse bench with great savings in space and labor and also avoiding attacks of mold fungi on the new foliage which are always a danger in grafting cases.

Once above-ground grafts tied with rubber and polyethylene strips have united and the scion is growing vigorously, the ties must be cut or they will constrict the graft. This can be very quickly done with a single-edged razor blade cutting down one side of the union. As previously stated, grafts tied with waxed string or grafting tape and planted with the graft union below the surface of the soil or the container medium do not need to have the ties cut, as they decay prior to causing any constriction of the scion.

It is possible in future years that micropropagation of difficult plants like oaks, beeches, and horse chestnuts by means of tissue culture will be worked out. Formerly very challenging trees like the purple-leafed, weeping, and fastigiate forms of the European birch (*Betula pendula*) are now easily grown in tissue culture. However, the others mentioned have been extremely resistant to micropropagation so far. In addition, working out the correct biochemical manipulation of a given woody tree or shrub is very costly, commercial laboratories quoting tens of thousands of dollars for a single plant. Therefore, for choice but rare plants like those named above, for which the commercial demand is limited, grafting is likely to remain the preferred method of propagation. Bench grafting, with the addition of new tying materials, is sure to be with us for many years to come.

The following woody trees, shrubs, and vines can be successfully propagated by bench grafting on bareroot understocks.

Acer palmatum clones. Grafts must be carefully callused to prevent premature bud break. Plant in shaded beds or in poly covered container houses.
Aesculus × *carnea* and *A. hippocastanum* clones. Graft on *A. hippocastanum*

seedlings. Use poly wrapped above ground grafts to retain sufficient root area on the understocks of these tap-rooted trees.

Amelanchier clones. Deep-planted bench grafts sucker far less than budded trees.

Betula pendula clones. Quickly branching clones like 'Fastigiata' produce little or no useable bud wood but are easy to graft.

Campsis clones. Grafted plants produce blooming size plants in one growing season.

Carpinus betulus clones. Large seedlings grafted with thick scions produce a saleable tree much more quickly than thin pot grafts.

Corylus avellana clones. Bench grafts sucker much less than pot grafts. Plant deeply in shaded beds or in containers in a poly house.

Ginkgo biloba clones. Ginkgos are difficult to bud and rooted cuttings grow much more slowly than bench grafts.

Hamamelis clones. Deeply planted bench grafts sucker less than pot grafts. *H. virginiana* suckers far less than *H. vernalis*.

Malus clones. Bench grafts sucker less than budded trees.

Prunus flowering clones. Thin-barked species like *P. subhirtella* are difficult to bud but graft easily.

Syringa vulgaris clones. Some choice lilacs are very difficult to root. Bench grafted shrubs on nurse roots are superior to budded plants.

Ulmus species and clones. Thin-wooded, twiggy species like *U. parvifolia* produce little useable bud wood but are easy to graft.

Wisteria clones. Softwood cuttings are difficult to root in wet summers and less vigorous than grafts. Deeply-planted grafts do not give suckering problems.

JOHN BAKKER: In your cold storage of the bare root grafts, how long can you hold them in storage and at what temperatures?

BILL FLEMER: We try to hold the temperature above freezing but below 40°F. We put them in from mid-February on and plant in early April. We have had no problem keeping them in storage if they have no leaf growth.

SAM JONES: Did I understand that you bare-root graft *Hamamelis*?

BILL FLEMER: We do them both ways.

CHIP BUDDING TECHNIQUES IN THE NURSERY

ROBERT H. OSBORNE

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Canada, EOE lPO

Chip budding is not a new technique. It has been used for decades and possibly for centuries. Recently however there has been a renewed interest in the technique. Much of the interest in North America has occurred as a result of British studies which have shown the technique to have many advantages over shield budding or T-budding. Before describing these advantages it might be advisable to describe the technique for those who are unfamiliar with it.

It makes no difference whether the stock or scion piece is prepared first, however we generally prepare the stock first. This reduces the handling of the scion piece and requires less juggling. The initial cut involves a downward thrust with a sharp grafting knife. The cut begins with a gentle curve until a depth equal to ⅓ of the stock's diameter is reached. Keeping the cut straight, proceed downward until the cut is approximately ¾ in. long. The length of the cut will vary somewhat with the size of the material being used. The second cut is made diagonally downward to meet the end of the first cut. The angle of this cut is usually about 30°. Our experience indicates that this cut is extremely important in the later healing process as it allows the cambium just below the bud to heal with the stock cambium, thereby helping the bud to continue growth after the budding process. We found in our initial attempts that those buds with a poor bottom cut would often die even though the chip itself would unite well with the stock.

After the stock has been prepared the scion piece is cut in precisely the same manner. The cuts should be made with one fluid motion rather than working your way through them. A flat cut is essential in order that no air spaces interfere with good cambial contact. It is important that the knife be very sharp so as not to tear the cambial cells and to facilitate the creation of flat surfaces. The bud piece is then slid into the stock being sure to gently but firmly lock the lower cuts. Align one side as perfectly as the cuts will allow. Hopefully the other side will match as well (Fig. 1). It is our experience that those buds which are matched on only one side are generally poorer growers if and when they heal. Although the cuts are very simple, an experienced budder is invaluable. The matching of the bud piece to the cut in the stock is critical to success and takes some practice to master. With experience the matching process becomes instinctive and a good budder can move very quickly.

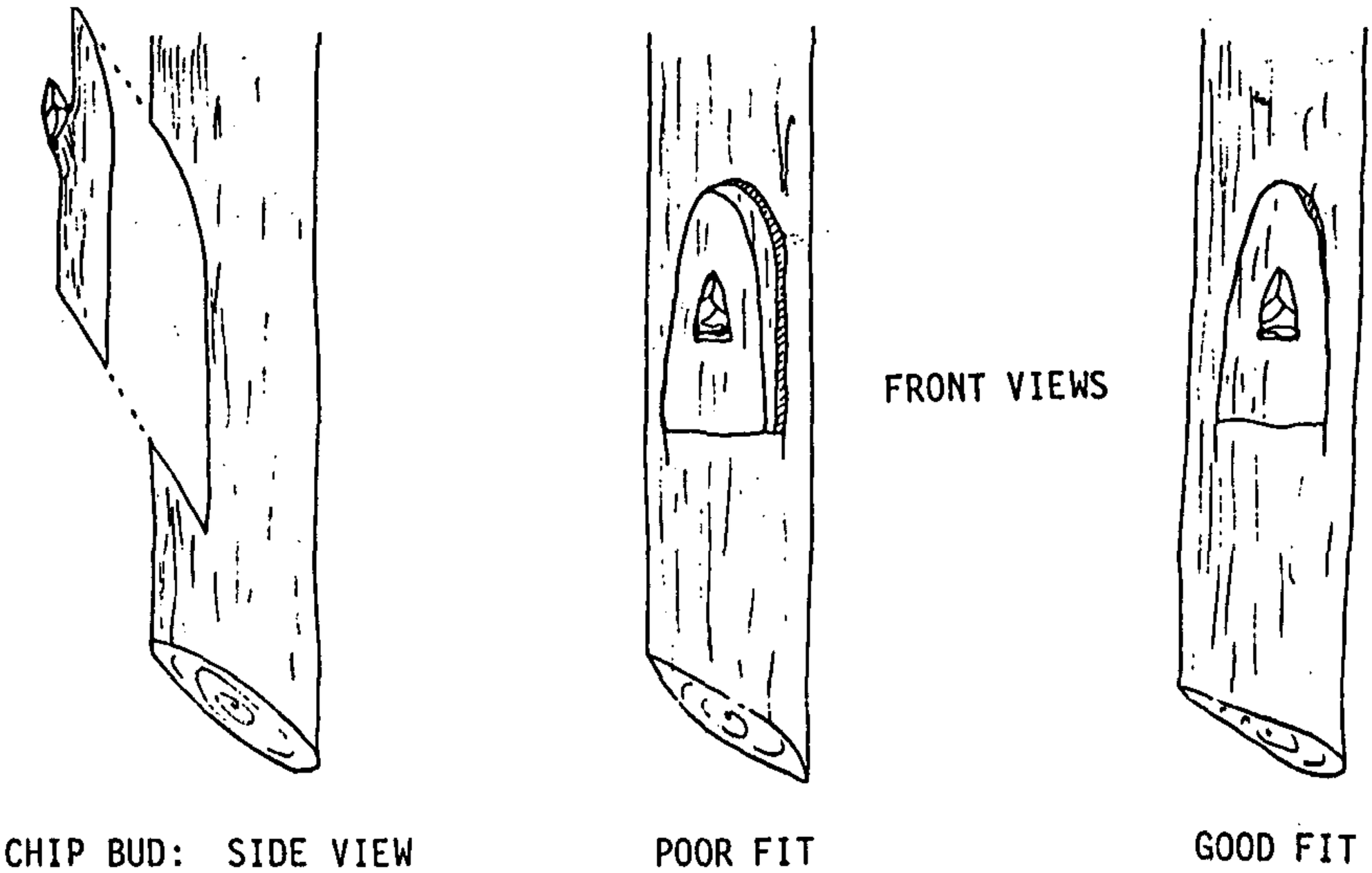

Figure 1. Steps in preparing the chip bud.

After the alignment is complete the bud must be wrapped in order to maintain moisture and exclude air which would dry out the cut surfaces. To our knowledge most growers using this technique rely on polyethylene strips for this purpose. We have been fortunate to discover a material called Parafilm®, made by the American Can Co. It is used as a laboratory film for covering beakers and such. It is a stretchy self-adhesive plastic material which is easy to apply, does not need to be tied and breaks down as the tissues expand. The bud has no problem breaking through the film and there is no need to go through the field later to untie the strips. For most of our budding needs we buy 4 in. wide rolls which we cut into ¾ in. strips. Only as many pieces as will be needed for the day are cut and care is taken to keep dirt from contaminating them. Generally the temperatures we experience during the budding season allow for just enough stretching for good pressure against the bud, however in very cold conditions the Parafilm® will have more tendency to break. In very warm conditions it can stretch a bit more than one might wish. Any drawbacks are more than offset by the product's virtues, particularly the fact that it does not need to be tied, thus reducing the time spent on each tree. We are quite fond of this material.

As the bud heals the Parafilm® will crack and by winter air will be able to circulate around the bud. A word of warning, however. If the stocks are growing very slowly or if your budding has been done late and the Parafilm® has not cracked before the onset of winter the

Parafilm® will retain condensation which will freeze and kill the buds. In this case you must cut away the film. On actively growing stocks budded at the proper time this is not a problem.

If budding is done in summer the stock will be cut back the next spring as is usual with other forms of budding. If done in the spring it is possible to cut the stock off immediately above the bud during budding; however we have found that our take has improved substantially by allowing the bud to heal for at least a week before cutting off the rootstock. It makes sense that the sap flowing past the cut surfaces will enhance the healing process. It is important that stocks not be allowed to grow too long, however, as this delays the transfer of apical dominance to the budded area, thus reducing subsequent growth of the bud. We generally cut off our stocks 2 weeks from the date of budding. Growth and care of the trees from this point is identical to trees budded by conventional methods.

Recently we have adopted the chip bud technique into the production of interstem trees, of which we produce a good number (Figure 2). In the past we had budded the interstem cultivar onto the rootstock the first year, then budded the cultivar onto the interstem the next year. Our new technique saves us a year.

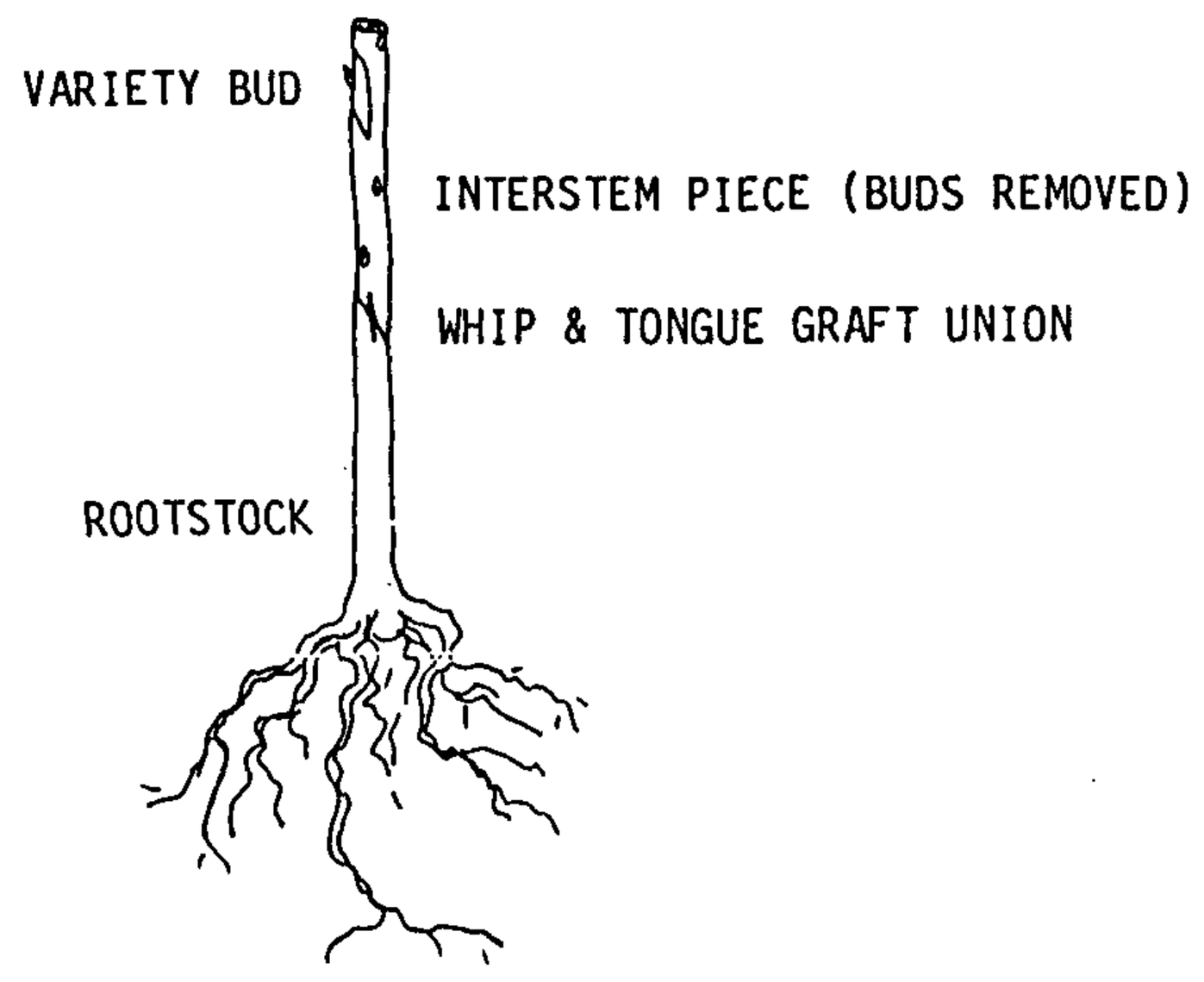

Figure 2. Use of the chip bud technique in producing interstem trees.

We gather fresh scionwood of the interstem cultivar from hedges grown specifically for this purpose. These are cut into lengths corresponding to the length of interstem desired. At this time they are also de-budded. The cultivar is then chip-budded onto the top of the interstem piece and sealed with Parafilm®. The

budded interstem piece is then whip and tongue grafted onto the rootstock. This graft is wrapped in Parafilm® and then brushed with a resin-beeswax-linseed oil preparation. We feel this gives the graft sufficient support for handling yet it does not need to be untied at a later date, which is the case if they are bound with budding rubbers. The completed trees are healed in sawdust in a vertical position at 4°C (approx. 40°F.) until the ground is ready for planting. This allows the bud and graft union to be at least partially healed before being set out. Although we do much of this indoors on the bench it is also quite feasible to prepare the interstem pieces indoors and then graft them onto rootstocks in the field. Growth on trees grafted in the field is quite vigorous. This technique not only saves a year of production time but produces a much smoother, straighter stem, a perennial sore point with interstem trees.

Many people have asked us why we chip bud? This is a fair enough question considering that the conventional T-bud is a time-tested, relatively easy, fast and reliable method of propagation. We feel, however, that chip budding offers several important advantages, some of which are universal and others which are particularly advantageous for our situation.

If we compare the T-bud with the chip bud technique we discover there is a subtle, but to us, important difference. The T-bud is inserted beneath a flap of bark and cambium tissue. As callus tissue from the stock's cambium and the bud's cambium start cell division they essentially fill the space between them with undifferentiated parenchyma cells until they meet and unite. Under good conditions with well managed material this process occurs within a few weeks (Figure 3). A chip bud, however, is a type of miniature graft. The bud is cut out of the scion stick and inserted in a matching cut made into the stock. The cambiums of each are placed into direct contact. Under normal conditions healing takes place rapidly because as

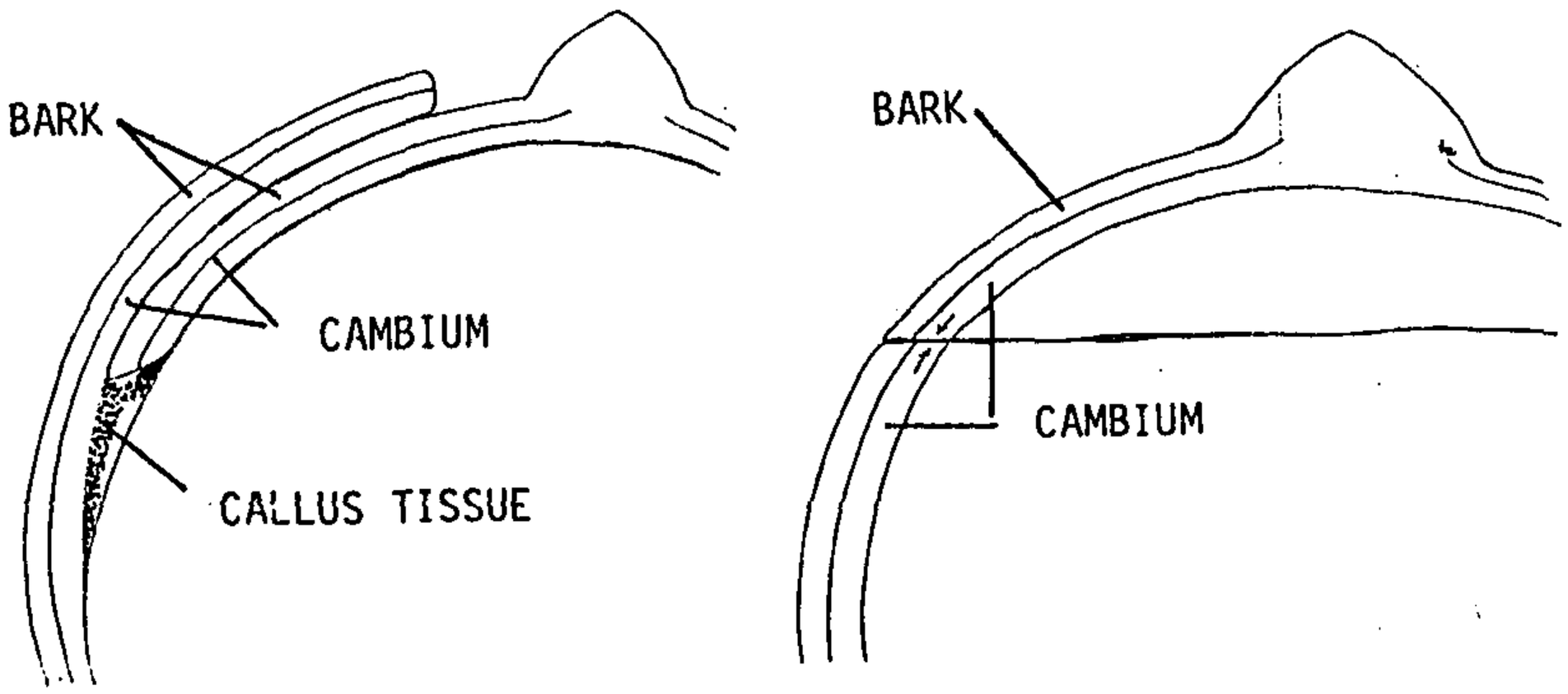

Figure 3. Tissues involved in healing of the T-bud and chipbud.

soon as callus production begins the cells come into immediate contact. Both techniques can and, of course, are successful methods to achieve the same end. The difference is in the speed of unification and, I would argue, the strength (at least in the short term) of the bond.

At our location in New Brunswick, Canada, our summer budding season is short. Our material is generally mature enough to bud by the first or second week of August. By the end of August and certainly by the beginning of September many localities around us have already experienced frost. While our particular location usually escapes these harbingers of winter, the point is that night temperatures by late August are very low. Our budding success using T-bud methods are often quite low. Even if our buds do unite well we often lose many to our very low temperatures in winter. We were searching for a method which would eliminate some of these problems. The rapid healing of the chip bud has helped us to increase our percentage of successful takes.

Another disadvantage to our site is wind. We are located on a hill which receives more than its share of breeze. It is great for keeping insects at bay but it also has the unfortunate habit of knocking newly healed budded shoots off their stocks. Our losses were quite high until we began chip budding. Inspection of wind-damaged trees usually showed that the callus tissue under the T-bud flaps had not formed sufficient fibrous strength to withstand our windy conditions, whereas the chip budded trees did not have the large quantity of undifferentiated, structurally weaker cells.

Another advantage that we find of great help is the ability to use much smaller scionwood than would ordinarily be possible with T-budding. The use of very thin budwood in T-budding will often result in a poor stand and larger scionwood is a decided advantage. Often the scionwood one has is either not as vigorous as would be desired or the cultivar being used produces small thin wood. The experienced chip budder can scale the size of the cut to match the size of the scionwood and we have been quite successful using scionwood less than ⅛ in. in diameter. If the budder is using very small buds the cut on the rootstock will be no more than a delicate shave and a small flap of bark for the bottom cut. This surface, if one examines it, will be entirely composed of cambial tissue, therefore when the bud is placed upon the stock there is a very good cambial contact taking place.

Conventional budding is nearly always done in late summer when the bark is slipping. Chip budding is far less limiting. Because it does not require the bark to slip it can be accomplished at any time during the growing season if dormant buds are available. In our climate we usually cannot complete our budding during the small "window" allowed us and we do a great deal of our propagation in spring. Not an enviable situation due to the pressures of our spring

season, but nevertheless a fact of life at our nursery. Without the chip budding technique we would be at a distinct disadvantage as we would need to graft all our material, a time-consuming process and one which uses more precious scion material than we can often afford.

I should point out in all fairness that it would be very difficult to argue that chip budding is as fast as T-budding. A good T-budder could probably keep ahead of a good chip budder under ordinary conditions. I will say that an experienced chip budder can do a lot of trees in a day and if those trees have a higher percentage of takes then the nursery certainly gains rather than loses in the long term.

We believe the chip budding technique can be of advantage to many propagators, whether or not it is used exclusively. As an example, failed trees which had been budded in the summer can be re-budded in spring using the chip bud to create better stands. This is particularly valuable if the cultivar in question is of high value. It is useful for such techniques as one-step interstemming and can be of value in the greenhouse as well. Whether or not you adopt chip budding on a large scale we think nearly every nurseryman can make use of this valuable technique. We urge you to try this technique if you have not already done so. You may find it will assist you in making your nursery more efficient and profitable.

CHARLES HILDEBRANT: What is the time of the year that you are doing your *Betula* grafts?

ROBERT OSBORNE: In mid-August in Canada.

A COMPARISON OF MEDIA COMMONLY USED FOR PROPAGATION OF RHODODENDRON CULTIVARS[1]

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Abstract. Commonly used propagating media were compared for efficiency and speed of rooting *Rhododendron* cultivars. Peat/perlite, peat/vermiculite, and vermiculite were found to be efficient when used at a depth of 19 cm under mist at a minimum temperature of 19°C. A 3 year comparison of the two peat mixtures showed peat-vermiculite to give the best results in the shortest time.

INTRODUCTION

The effect of propagating media on root initiation has been studied for over 60 yr. Long (16) found that medium factors essential for rooting included aeration and water content. He found these not only influenced rooting percentage but also root texture. Roots developed in a medium with high water content were more brittle and less fibrous. Others have since supported these observations though controversy has arisen because different plants were used in each experiment, and environmental conditions also varied (1, 4, 5, 10, 13, 26).

More recently, medium depth was found to strongly influence aeration (8, 12, 18). Lunt (17) found a coarse medium in a shallow container would retain as much water as a clay soil in the field, regardless of whether the medium was amended with organic matter or not. When Paul (21) compared 13 media under frequent irrigation, he found they had a range of percent free pore space of from 0 to 20 at container capacity at a depth of 12 cm. He found media with organic matter at 40 to 90% (v/v) had the best aeration and concluded that a medium of equal parts vermiculite and peatmoss was the best of those tested. He also noted that the measurement of percent free pore space was not as reliable as measuring oxygen diffusion rate as an indicator of a well aerated media.

Reisch (25) published a comprehensive review of research of propagating media. He concluded that many materials could be used as propagating media as long as they provided ample drainage and aeration. He recommended the medium be as deep as possible. He noted that success depended upon both the physical properties of the medium and the management program. Reisch felt that the apparent contradictions in the literature could be attributed to a failure by researchers to recognize or report differences in compo-

[1]Approved by the Director of the Rhode Island Agricultural Experiment station, Contribution No. 2351. Research was supported in part by funds from the Hatch Act. Appreciation is expressed to William A. Johnson, Research Asssociate, Dept. of Plant Sciences, U.R.I., for the assistance of statistical analysis.

nents of media and environmental conditions. Two such differences are pH of medium and temperature.

While pH has been found to influence rooting of *Thuja* (2), balsam poplar (6), and chrysanthemum (6, 19, 20), it had little effect on rooting of other woody plants, including rhododendron (7). There is some evidence that soil pH of stock blocks may influence subsequent rooting of cuttings (29).

Temperature has been reported to play an important role in root initiation. Optimum temperatures as high as 29°C have been reported (15). Optimum temperature for rooting rhododendron cuttings has been reported to be 25°C (28). Dykeman (9) found that the optimum temperature of root initiation was higher than that required for root development on forsythia. He found optimum temperatures for initiation ranged from 27 to 33°C while those for root development were 17 to 25°C. Unfortunately, few other researchers have reported that they manipulated temperatures during the two processes. Turner (28) rooted 22 cultivars of rhododendron in a pulverized pine bark medium at 25°C while maintaining the air temperature at 10 to 12°C. This is a common commercial practice for fall propagated woody crops.

Research reports on propagation of rhododendron and other crops often do not include the time required for rooting, yet when one considers the cost for fuel required to maintain a minimum temperature of 25°C it should be considered.

Kinsey (14) propagated rhododendron in 2 to 3 months while Proebsting (24) allowed them to remain in the bed 4 to 5 months. Smith (27) made his final harvest after 17 weeks. Turner (28) however, propagated most of the 22 cultivars he tested in 8 weeks. The time required to root rhododendron cuttings obviously can be reduced if one maintains the optimum temperature and a well aerated medium (11).

Research has been done to find substitutes for sphagnum peatmoss as the source of organic matter for propagation and container plant production (22, 23, 28). This is being done because of a decline in availability and increased cost. Other sources of organic matter have served equally well as long as they met the criteria of a good medium, i.e., they should have a free pore space of 18 to 20% and a depth of at least 10 to 12 cm.

The present work was done as part of a regional project, (NE 136, Engineering greenhouse and other controlled plant production systems). One objective was to develop efficient production methods of woody ornamentals at low cost. One of the greatest costs in the northeast is fuel, and this cost can be reduced if the time required to produce the crop is reduced. One approach was to identify propagating media which would provide an environment for rapid propagation of a major crop in the region. The rhododendron was chosen since high optimum temperatures are required

for that crop. Summer propagation was done to further reduce but not eliminate heating costs.

PROCEDURES

Commercially accepted propagating media were compared for the efficient propagation of hybrid rhododendron cultivars in the summers of 1984, 1985, and 1986. Cultivars used were: 'Boule de Neige', 'English Roseum', 'Nova Zembla', 'P.J.M.', 'Scintillation', and, 'Chionoides'. Not all cultivars were tested every year, nor were all media compared every year. Those media which provided best rooting were tested in subsequent years.

All media were passed through a 0.5 cm screen before being placed 18 cm deep over a coarse gravel base in raised propagating beds in a heated plastic-covered greenhouse. In addition, bottom heat was provided in the beds and maintained at a minimum of 19°C. This is below the 25°C optimum temperature reported to be required for the crop (28).

Media were not sterilized in 1984 or 1985, but those media that were reused in 1986 were sterilized with methyl bromide in 1986. Media used were: sphagnum peatmoss, sphagnum peatmoss/medium grade vermiculite, sphagnum peatmoss/medium grade perlite, medium grade perlite/shredded pine bark/sphagnum peatmoss, medium grade vermiculite, shredded pine bark, a commercial mixture of sphagnum peatmoss/vermiculite, decomposed granite, commonly referred to as rotted rock, and decomposed granite/medium grade perlite. Media components were always mixed in equal parts by volume.

Cuttings were trimmed to a length of 11 cm and all but the uppermost five leaves were removed. The remaining leaves were trimmed to one half their original length. Cuttings were wounded bilaterally on the lowest 2 cm as is the common commercial practice. They were treated with one of two growth regulators: Hormex, a commercially available talc formulation containing 4.5%, 3-indolebutyric acid (Brooker Chemical Co.), or an aqueous 5-sec. dip of a mixture of 3-indolebutyric acid and 0.5% naphthaleneacetic acid in a solvent of 40% Carbowax (Union Carbide). This mixture was diluted with water to solutions of 1:3 or 1:5, depending on the maturity of the crop being propagated. Specific crops used, dates propagated, and growth regulators applied are listed in the tables under results and discussion.

Cuttings were taken on dates when it was deemed they were sufficiently mature for propagation. They were placed in the propagation beds so that cut ends of leaves did not touch. Intermittent mist was applied at 6 sec/6 min during the daylight hours. The propagating house was cooled by fans and it was shaded to provide 44% shade. Cuttings were placed in a randomized plot design in

three replicates of five cuttings each. All cuttings of any cultivar were harvested when one treatment of that cultivar was found to have rooted sufficiently.

Data recorded were: percent free pore space of media as outlined by Buscher and Van Doren (3); pH, percent rooting, average rootball diameter, and date of harvest. Data from rootball diameters were analyzed statistically by analysis of variance and means were separated by Duncan's multiple range test.

RESULTS AND DISCUSSION

The pH of the media varied from 4.2 to 7.5 but did not appear to have a direct influence on rooting percentage or rootball diameter (Table 1). This is similar to results found by Paul (19). Percent free pore space was variable. This can be attributed to the lack of precision of the method. However, those media producing best rooting consistently had a percent free pore space of 20 to 23%, (Table 1).

Table 1. Comparison of different propagating media for rooting cuttings of selected rhododendron cultivars

Media	pH	Percent free pore space	Cultivar			
			Boule de Neige		English Roseum	
			Av. rootball diam. (cm)	% rooted	Av. rootball diam. (cm)	% rooted
Peat/Vermiculite	5.5	22	4.69 a[1]	96	3.54 a	100
Peat/Perlite/Bark	5.8	20	4.25 a	96	3.54 a	92
Vermiculite	7.0	23	3.83 ab	84	2.13 b	92
Granite/Perlite	7.0	23	2.93 bc	92	1.79 b	88
Pinebark	6.8	18	2.56 bc	44	2.21 b	84
Commercial mix (peat/vermiculite)	7.5	18	2.53 bc	48	1.86 b	72
Granite	7.0	14	2.43 c	52	1.35 b	96
Peat/Perlite	4.2	14	2.21 c	68	1.45 b	52

[1] Means followed by the same letter within cultivars are not significantly different at 5% level.

While rooting was variable from year to year, which is normal, a medium of peatmoss and vermiculite consistently produced good rooting and large rootballs in the least time (Table 2). This supports results found by Paul (21), and shows that even though cuttings were allowed to remain in the propagating bed for 8 to 10 weeks, they could probably have been harvested in less time with a rootball sufficiently large to sustain growth. This could result in lower production costs and possibly allow for faster crop rotation. Obviously, cultivars vary in time required for rooting, but there was little evidence that the type of growth regulator used greatly

influenced rooting results. It should also be noted that keeping the minimum temperature at 19°C instead of 25°C did not appear to reduce time required for rooting. However, this work was done in the summer when maximum temperatures exceeded 25°C in the daytime.

Table 2. A 3-year comparison of rootball development in two propagating media commonly used for rhododendron cultivars.

Cultivar	Av. rootball diam. (cm) Peat/vermiculite	Peat/perlite	Av. no. weeks
'Boule De Neige'	3.83 a[1]	2.66 b	9
'English Roseum'	4.21 a	4.74 a	10
'P. J. M.'	4.42 a	3.32 b	8

[1] Means followed by the same letter within cultivars are not significantly different at 5% level.

The improved rooting in sterilized medium is also worth noting (Table 3). While it was not consistent for all cultivars, it did appear to stimulate faster rooting in two cultivars. If this proves to be consistent in future tests it would enable the propagator to reuse media at least once and reduce operating costs. It did not appear to reduce percent free pore space.

Table 3. Comparison of sterilized and non-sterilized media of peatmoss and vermiculite in rooting cuttings of rhododendron cultivars.

Cultivar	Sterilized media		Non-sterilized media	
	Av. rootball diam. (cm)	% rooted	Av. rootball diam. (cm)	% rooted
'English Roseum'	7.42 a[1]	100	4.03 b	85
'P. J. M.'	4.81 a	85	4.72 a	85
'Scintillation'	4.24 a	80	4.15 a	65
'Nova Zembla'	5.01 a	90	3.52 a	85
'Boule De Neige'	5.12 a	100	1.98 b	45

[1] Means followed by the same letter within cultivars are not significantly different at 5% level.

This was not an exhaustive study of all possible propagating media that could be used to propagate this crop, but it does show that several may be used very effectively. It should be noted that when cuttings in one medium were ready for harvest, all cuttings of that cultivar in all media were harvested. If those cuttings that were poorly rooted but had similar rooting percentages had been permitted to remain in the mist bed, they would have had improved rooting, but this was a study in which time was the critical factor. It was the objective to find media that would produce well rooted cuttings most rapidly. Table 1 indicates that three media produced well rooted cuttings: peat/vermiculite, peat/perlite/bark, and vermiculite, but only one was studied further. Results with peat/perlite were not good but this medium was studied in each successive year because it is the most widely used medium in the commercial trade

for propagation of rhododendron. Vermiculite was not studied further. While it is a good medium with some water supplies, when used with no organic matter, it can be a problem if the water in the mistline contains copper or manganese because of the effect of high pH on availability of these metals. The organic matter acts as a buffer and ties up ions in solution (Personal comm. Dr. William Krul, Dept. Plant Science, Univ. R.I., Kingston, R.I.). In later work it was found that mixtures with bark were too variable as particle sizes were difficult to standardize and for that reason that medium was also discontinued. Peat/perlite mixtures produced better rooting in subsequent studies than it did in 1984 (Table 2).

Further work is under way to study the apparent effect of sterilization of the media with methyl bromide and to more accurately determine the optimum temperature for propagating these rhododendron cultivars. This work will be published at a later date.

At this time it is the conclusion of the author that a medium grade vermiculite and screened sphagnum peatmoss medium (1:1, v/v), that has been sterilized with methyl bromide and placed at a depth of at least 18 cm will provide the best rooting medium for the cultivars of the hybrid rhododendrons tested. This is significant because at this time it is not widely used by commercial propagators for this crop. It is further recommended that a minimum temperature of 19°C is sufficient in summer propagation to produce well rooted cuttings in 8 weeks or less if they are made when they are in a semihardwood condition. The medium can be reused at least once if it is sterilized with methyl bromide. While it is recognized that the most commonly used medium for propagation of this crop is peat/perlite the evidence presented here shows a medium of peat/vermiculite is superior and should be tested if time is a cost factor. If time is not an important parameter several media may be used equally as well.

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HEATH AND HEATHER PROPAGATION

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Heaths (*Erica*) and heathers (*Calluna*) are members of the Ericaceae family, which contains about 70 genera with approximately 1500 species distributed through both hemispheres. *Erica* is one of the largest genera, with some 500 species that are found chiefly in South Africa, also in the Mediterranean region, as well as Central and Northern Europe. The South African species are not hardy in northern climates, but several are useful ornamentals in the U.S. Southwest as well as for the cut-flower trade. The Mediterranean species are cold hardy to +10°F (+5°F with winter protection). It is the group from the less temperate regions of Europe that we are chiefly concerned with, species with cold hardiness ratings that range from −5 to −35°F (*E. carnea*, *E. cinerea*, *E.* ×*darleyensis*, *E. tetralix*, *E. vagans* and *E.* × *williamsii*). There are other genera that are called heaths that can be grown in northern climates; they are the spike heath (*Bruckenthalia*), the Irish heath (*Daboecia*) and the mountain heaths (*Phyllodoce* spp.), as well as members of the allied genus *Cassiope*. Heather (*Calluna*) contains but one species, that being *C. vulgaris; its distribution is from Europe to Asia Minor.* Luckily, heathers produce sports from which over a hundred named cultivars have been selected. Heathers are cold hardy to about −20°F but some cultivars with yellow foliage will not tolerate hot humid conditions without light shade; as a result there are very few yellow-leaved cultivars that are worth commercial production in the U.S. Northeast. In the U.S. Northwest and Europe this is not a problem.

Heaths and heathers sold in the Northeast are low growing evergreen shrubs that range in heights from 3 in. to 3 ft, when grown in the milder areas of our region. They are not widely used in landscape situations because they require winter protection. They are worth the trouble though, for few other plants give so much color for so long a period of time. Collectively, their flowering season spreads throughout the whole year and there are forms with foliage of red, orange, yellow, gray, bronze and rich greens that provide a continuous display. Only dwarf conifers come close to providing such a show and they do not produce the showy display of bloom. The two groups are often planted in combination, for dwarf conifers provide interesting contrast in texture and height.

PROPAGATION

The IPPS Proceedings contain three articles on this subject (see "Additional Reading" below). In the interest of brevity I will not

compare techniques, but just discuss how White Flower Farm propagates heaths and heathers.

Source of cutting material. 1) *Stock plants.* We have recently established a stock block for heaths and heathers. These plants are grown on a west facing slope and the area was treated with Round-Up before planting to eliminate perennial weeds. Generous quantities of peatmoss were added to the soil before planting to provide the abundant moisture that they need and also to lower the pH of the soil to between 5.0 and 5.5. They are mulched with 2 to 3 in. of pine needles that we buy from South Carolina. During the winter we will lay pine boughs over the plants and put up snow fence to trap snow and protect them from wind desiccation. We expect lows of −20°F every second or third winter and if this happens with no snow cover and high winds the evergreen foliage of heaths and heathers is freeze-dried with devastating results.

2) *Saleable plants.* Judicious pruning of the salable plants that is necessary in the late summer also provides cuttings at propagation time. Some cultivars are slow growing and do not provide us with the quantity of cutting material we need, hence the need for a stock block.

3) *Display border.* This is located close to our retail outlet and we use these plants as a last resort so as not to spoil the display.

Propagation timing. We have found it necessary to propagate *Erica vagans* cultivars when they are in soft growth in June and July. Other *Erica* species and cultivars, as well as *Bruckenthalia, Calluna* and *Daboecia*, are propagated in early to mid-September. We occasionally have to root make-up cuttings as late as November; they root satisfactorily but propagation at this time of year does not fit our production cycle as well. Late propagation also necessitates the use of much warmer greenhouse temperatures for growing on the rooted cuttings: 60°F instead of our usual 40°F.

Propagation environments. 1) For heathers (*Calluna*) we use unheated outdoor frames that are 6 × 60 ft and covered with clear polyethylene, supported by a pipe-frame structure. These frames are oriented east-west and the south side has doors for access and ventilation. There is no bottom heat and mist is provided by 180° nozzles that spray from one side of the frame. The frequency is controlled by a timer with a 6 min frequency setting and with multiple 6 sec duration tabs. At first a double 6 sec burst is used every 3 min; after a week or so this is reduced to single bursts, then one burst every 6 min, and after 3 or 4 weeks the mist is turned off.

2) For heaths (*Bruckenthalia, Daboecia* and *Erica*) we have found it necessary to root these in a glasshouse with mist and 70°F bottom heat. Last year we built two propagation chambers within our Lord and Burnham glasshouse. These are approximately 24 ft sq with independent heating and ventilation. They were walled off with double-walled polycarbonate panels to provide environments

that could be controlled accurately. We use them for a wide assortment of perennials and shrubs, including the heaths. All cuttings are stuck in flats or multipots to allow us the flexibility of removing them as soon as they are rooted, permitting multiple-use of this area.

Rooting containers. We have always used wooden flats that measure 22 × 11 × 3 in., but recently we started to use rigid plastic flats. These work just as well, will be easier to pasteurize, and will last much longer.

Rooting compost. For both heaths and heathers we use equal parts of peat moss and coarse perlite. We have found it better to mix this by hand as our soil-mixing machine pulverizes the compost too much and thus reduces the air content drastically, especially after several weeks under mist. As we fill the flats for heathers we first put down a 1-inch layer of compost then sprinkle 1 tablespoon Osmocote 18-6-12 slow release fertilizer to provide nutrients for the cuttings as soon as they are rooted; the flats are then filled to the top. The fertilizer in Osmocote is released before heaths have rooted and, in our experience, this inhibits rooting; therefore, for heaths we sprinkle 1-tablespoon Osmocote 18-6-12 on the surface of the compost after rooting.

Rooting aid. We use Hormo-Root B for all our heaths and heathers. This contains 15% Thiram and 0.4% IBA in talc.

Harvesting and preparation of cuttings. We take a day's supply of cuttings early in the morning and place them in plastic bags in a refrigerator until they are needed. Depending on the vigor of the cultivar, cuttings are taken from 1 to 3 in. long, branched shoots preferably. Foliage is stripped off the lower half-inch, the cuttings are dipped in Hormo-Root B, and stuck 80 to a flat. We use an 80-nail marking board to space the cuttings evenly. Cuttings are watered in gently and placed under mist.

After rooting treatment. The flats of rooted cuttings are moved to a polyhouse which is kept at a nighttime temperature of 50°F for the first two months and then dropped to 40°F for the remainder of the winter. Daytime temperatures are 10°F higher. Vigorous cultivars are sheared to promote branching. As the days get longer in late winter the young plants are fed every two weeks with 20-20-20 liquid fertilizer used at half strength for the first 4 applications then given two full strength feedings just before potting in April. During the winter the only problems that appear are the occasional weed, which we pull by hand, and liverworts, which are controlled with drenches of Thiram at 4-teaspoons per gal of water.

Potting the rooted cuttings. We use two sizes of plastic pots, a 2 qt square pot and a deep 3 pt square pot for the less vigorous cultivars. Our potting compost is mixed by a soil-mixing machine and consists of:

9 bags of aged pine bark [27 ft^3]

2 bales of peat moss [15 ft^3, loosened]
2 bags of coarse perlite [12 ft^3]
10 lb agricultural gypsum
10 lbs dolomitic limestone
3 lb Micromax trace-element mix
3 lb superphosphate [0-20-0]
4 lb potassium nitrate [13-0-44]

We use a knife to separate the young plants before potting them on a Bouldin and Lawson potting machine. The freshly potted plants are placed in rigid plastic trays and placed in a polyhouse. The trays were obtained from Holland with our lily bulb shipments. By the middle to end of May we remove the polyethylene and replace it with 40% polypropylene shade cloth which we leave on for the first month.

Summer treatment. This consists of watering overhead and occasional spot watering by hand; feeding—injected into the overhead water using 20-20-20; weeding—mostly bittercress and dandelions which are removed by hand; spraying for what we call summer botrytis (*Pestaloptiopsis* sp.) with a combination of Benlate (benomyl) and Manzate at ½ tablespoon and 1½ tablespoon per gal of water, plus a spreader/sticker; shearing—this is done by hand on the vigorous types only and early flowering heaths are not sheared after July 1st to avoid cutting off next year's flower buds.

Winter treatment. The root killing temperature of container grown heaths and heathers is about 15°F and so we set the heat at 20°F. To make sure that they are completely dormant, this crop is the last to be covered with polyethylene. All our polyhouses are double-skinned and air-inflated. For the heaths and heathers we use white copolymer polyethylene over a layer of clear plastic to reduce temperature fluctuations. We once tried barrels of water painted black to hold residual heat; instead they froze in the early part of the winter and remained solid blocks of ice till spring. High humidity on sunny days is removed by opening the doors at both ends of the house; if available, forced air ventilation would be better. We have a preventative spray program of Benlate and Zyban during the winter to reduce *Botrytis* infestations. Watering is not needed very often during the winter months and is usually done by hand when necessary.

Shipping. Shipping is done in early fall only to locations south of Litchfield, CT. Fall planting is not recommended to areas where the winter temperatures go below −20°F. None are shipped after October 15th. In spring we ship to southern states starting in late March and finish all shipping by June 1st.

ADDITIONAL READING

Cross, J. E. 1972. Propagation is just the beginning. *Proc. Inter. Plant Prop. Soc.* 22:345–349.

Cross, J. E. 1976. *Calluna* and *Erica* production and distribution. *Proc. Inter. Plant Prop. Soc.* 26:228–232.
Kelly, J. C. and Bowbrick, P. 1973. The rapid production of ericas, callunas, and daboecias. *Proc. Inter. Plant Prop. Soc.* 23:121–129.

PRE-EMERGENT HERBICIDE EFFECT ON THE ROOTING OF CUTTINGS

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Abstract. Unrooted cuttings of *Rhododendron obtusum* 'Hino Crimson', *Euonymus fortunei* 'Emerald Gaiety', *Ilex crenata* 'Helleri', and *Cotoneaster horizontalis* were treated with Dual, Devrinol, Ronstar, Surflan, and Rout. Cuttings were then allowed to root under intermittent mist in a polyethylene greenhouse, and were later evaluated for rooting percentage and rooting quality. When compared to the untreated check, results indicated no significant difference with the use of Ronstar as a pre-rooting herbicide treatment for *R. obtusum* 'Hino Crimson', *E. fortunei,* and *I. crenata*. Likewise, Rout showed similar results for *R. obtusum* 'Hino Crimson' and *E. fortunei* 'Emerald Gaiety'. All other herbicide treatments demonstrated poorer results of either percentage or quality of rooting on the species tested.

REVIEW OF LITERATURE

In southern New Jersey, many growers of woody nursery stock root their cuttings in outdoor beds or in open greenhouses. Each year, from grower experience, weed seeds apparently are blown onto the rooting medium and cause subsequent expenses in hand weeding. The weed growth also results in reduced growth of the cuttings through competition and/or mechanical disruption during the weeding process. A previous study indicated some potential for using several pre-emergent herbicides during the rooting phase of cuttings. This study was initiated to further determine the potential for using pre-emergent herbicides as weed control agents on unrooted cuttings, while examining their effect on rooting ability and quality of rooting.

MATERIALS AND METHODS

Cuttings from four species; *Rhododendron obtusum* 'Hino Crimson' (Hino Crimson azalea), *Euonymus fortunei* 'Emerald Gaiety', *Ilex crenata* 'Helleri', and *Cotoneaster horizontalis* were taken on July 24, 1986. A quick-dip hormone (Dip 'n' Grow diluted 10:1 for *Ilex* and 20:1 for all other species) was used on the cuttings which were stuck in 3 × 3 × 3.5 in., #18 cell trays. The medium was a mix of peat:vermiculite:perlite:sand (70:10:10:10, v/v/v/v), and

Cross, J. E. 1976. *Calluna* and *Erica* production and distribution. *Proc. Inter. Plant Prop. Soc.* 26:228–232.
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contained 5 lb of dolomitic lime, 1.25 lb of 0-46-0, 0.5 lb of 0-0-60, 3 oz of fritted trace elements, and 1.5 pt of a granular wetting agent per yd.[3] Cuttings were misted with low volume (0.45 gpm) sprinklers on a time clock system after being treated with the herbicides on the date of propagation.

All treatments were replicated nine times. Treatments included: an untreated check, Dual (80EC) at 4 lb ai/acre, Devrinol (10G) at 3 lb ai/acre, Ronstar (50WP) at 4 lb ai/acre, Surflan (75WP) at 3 lb ai/acre, and Rout (3G) at 100 lb ai/acre (Surflan at 1 lb ai/acre plus Goal at 2 lb ai/acre). Herbicides were applied on a sunny day with a temperature of 90°F and a relative humidity of 66%. After the treated cuttings had dried, all cuttings were watered heavily. Evaluation of the cuttings was based on a 1 to 9 quality rating system (1 = unrooted, 9 = best rooting) on October 9, 1986. Cuttings were also checked for rooting percentage. Analysis was conducted within species and is reported as the least significant difference at the 5% confidence level.

RESULTS AND DISCUSSION

Evaluation for rooting percentage indicated the untreated cuttings were either the best treatment or were not significantly different from the best treatments (Table 1). In both the azalea and cotoneaster treatments, cutting rooting percentage was reduced by Surflan. Additionally, rooting percentage of cotoneaster was reduced by Dual, and Devrinol. There was no reduction of rooting percentage with any treatment for either *Ilex* or *Euonymus*.

Table 1. Rooting percentage of cuttings by species with various treatments.[1]

Treatment	Species			
	Rhododendron	*Ilex*	*Euonymus*	*Cotoneaster*
Untreated	78ab[2]	100	100	100a
Dual	67b	100	100	33d
Devrinol	100a	100	100	78c
Ronstar	89ab	100	100	100a
Surflan	22c	100	100	89b
Rout	78ab	100	100	100a

[1] Evaluated October 9, 1986.

[2] *Percent rooting. Figures in the same column followed by the same letter are not significantly different at the* 0.05 level.

The evaluation for rooting quality again indicated that no treatment was significantly better than the untreated check (Table 2). In azalea, *Ilex*, and *Euonymus*, the Ronstar treatment was not significantly different from the check. Other treatments not significantly different from the checks were Devrinol and Rout on azalea, and Rout on *Euonymus*. It is interesting to note that no treatment performed as well as the untreated check on cotoneaster which was the only deciduous species in the experiment.

Table 2. Rooting quality of cuttings by species with various treatments.[1]

Treatment	Species			
	Rhododendron	*Ilex*	*Euonymus*	*Cotoneaster*
Untreated	4.11a[2]	7.44a	8.44a	6.67a
Dual	1.67b	3.44c	3.89c	1.56d
Devrinol	3.44a	5.00b	4.00c	4.00c
Ronstar	4.56a	7.44a	8.89a	4.67bc
Surflan	1.33b	3.44c	7.56b	4.33bc
Rout	3.67a	5.44b	8.78a	5.11b

[1] Evaluated October 9, 1986.
[2] Rooting quality based on a 1–9 scale (9 = best). Numericial ratings in the same column followed by the same letter are not significantly different at the 0.05 level.

A review of the results by herbicide reflected the activity of each herbicide (1). Dual has limited soil mobility, and has season-long residual activity. It inhibits root elongation, and resulted in a reduction of the rooting quality in all species. In *Ilex*, roots were gnarled and restricted close to the cutting shoot. In the other species, root density was generally reduced. Rooting percentage was reduced in azalea and cotoneaster, but not in *Ilex* and *Euonymus*. Both azalea and cotoneaster have more succulent leaves which could absorb far greater quantities of herbicide than the waxy leaves of the *Ilex* and *Euonymus*. Translocation of the herbicide could have caused the reduction in rooting percentage in those two species. The quality of rooting might result from Dual being absorbed through newly emerged roots and then inhibiting subsequent root activity.

Devrinol is taken up by the roots and has a long residual in the soil. Inhibition was primarily in rooting quality and not in rooting percentage. Roots apparently are initiated, absorb the herbicide, and are then injured. The results are bulbous roots in azalea, and root restriction close to the medium surface in *Ilex* and *Euonymus*. Devrinol has limited soil mobility in the peat-based medium which was demonstrated by injury to the roots which did not extend more than ½ in. below the medium surface.

Ronstar is primarily a contact herbicide, although there is possible translocation in susceptible plants. Results in rooting percentage indicated no differences between the treated cuttings and the untreated check, which would be expected. Based on rooting quality, cotoneaster was the only species to exhibit any root inhibition, and resulted in reduced root density. Possibly cotoneaster leaves are sufficiently succulent to allow for foliar absorbtion and subsequent translocation of Ronstar which resulted in root inhibition.

Surflan affects physiological growth processes. It is absorbed by the roots, and has a full season residual in the soil. Inhibition of rooting percentage was noted in azalea and cotoneaster, while rooting quality was negatively affected across all species. The

severity of rooting percentage inhibition in azalea is interesting to note, and may be the result of susceptibility of that cultivar to Surflan. Also of interest was the ½ in. root restriction from the medium surface in *Ilex*, which was very similar to the restriction noted with Devrinol applied to *Ilex*.

Rout has the activity of Surflan at 1 lb ai/acre rate (instead of the normal 3 lb ai/acre rate) in combination with Goal, which is a contact herbicide, at the 2 lb ai/acre rate. Goal is not soil mobile. Rooting percentage was unaffected by this treatment, while a reduction in root quality was noted only in *Ilex* and cotoneaster. Both *Ilex* and cotoneaster were also the most affected species by Surflan alone and therefore the reduction in root quality may be attributed to the Surflan. *Ilex* had a notably looser root-ball with this treatment than in the untreated check.

CONCLUSIONS

When a weed problem occurs on a continuing basis, growers should first implement additional sanitation procedures. When those measures give less than desirable results, then the grower should evaluate the potential for using herbicides to control the problem. If success can be assured, the use of herbicides could prove to be a cost-effective alternative to hand-weeding. When rooting cuttings, however, the primary goal must remain that of success in rooting percentage and quality.

This study has indicated a potential for using Ronstar as a weed control agent for *R. obtusum* 'Hino Crimson', *E. fortunei* 'Emerald Gaiety', and *I. crenata* 'Helleri'. Although the rooting percentage of *C. horizontalis* was unaffected by Ronstar, the rooting quality was inhibited, and therefore should not be considered as a weed control agent on this species. Results of the Rout treatment also demonstrated the possibility of using that herbicide on *R. obtusum* 'Hino Crimson' and *E. fortunei* 'Emerald Gaiety'. All other herbicides tested did not exhibit consistent positive results, and should not be considered for use during the rooting of cuttings on the species tested. Further evaluation should be conducted to determine the potential for using these and other herbicides during the rooting phase of cuttings, and to demonstrate year-to-year replication of the Ronstar and Rout results.

LITERATURE CITED

1. Beste, C. E. 1983. Herbicide Handbook of the Weed Science Society of America. 5th ed. Weed Science Society of America, 309 West Clark Street, Champaign, IL 61820.

THURSDAY MORNING, DECEMBER 11, 1986

The Thursday morning session convened at 8:00 a.m. with David Hensley serving as moderator.

A SYSTEMATIC APPROACH TO GROUNDCOVER PRODUCTION

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Midwest Groundcovers

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A "system," according to Webster, is "a scheme, plan or method," or "a regular method or order". If this definition were interpreted for ground cover production, it may read, "a consistent method for producing groundcovers". At Midwest Groundcovers, we have always felt the need for a system, because of the large number of units involved. We have also found that as the components within the system change in size or nature, the entire system may need to be modified to compensate for these changes. This will be the thesis for this presentation based on our experiences at the nursery. The system which will be looked at is the production of groundcovers, from the making of cuttings to the loading of the flats on the customer's trucks.

To start out, let's set some parameters on this discussion. The crops which are included are *Pachysandra terminalis* 'Green Carpet', *Euonymus fortunei 'Colorata'* and *Polygonum cuspidatum* var. *compactum*. The cuttings are direct stuck in 2 in., 3 in, or quart pots in flats. The 2 and 3 in. pots have two cuttings per pot and the quart has 3 cuttings per pot. The cutting season varies with the crop: *Polygonum* is May 15 to July 1, *Pachysandra* is June 15 to August 10, and *Euonymus* is June 15 to September 15. The yearly production of groundcover units has been increasing every year since the company began in 1969. In 1982, there were about 1,100,000 groundcover units of these species produced. By 1984, production was up to 1,500,000, a 36% increase. These rapid increases greatly stressed our propagation facilities and production system. We had to re-evaluate our current system, make changes and come up with a new system. In this presentation, we will review, the "old system" with the problems that were experienced and the decision to build the "new system," and then look at the new system that was developed for producing groundcovers.

First of all, let's take a look at the "old systems" facility. It was a 5 acre nursery located 3 miles south of the main nursery. In those 5 acres, there were about 91 beds suitable for groundcover propagation, with an average capacity of 310,000 units. The beds were 6 ×

40 ft., unheated, and of simple construction. When *Polygonum* cuttings were being rooted in the frames, they were covered with white plastic. If the crop was *Pachysandra* or *Euonymus* the frames would be covered with 55% shade cloth. The covering material was suspended on a 10 foot piece of electrical conduit bent in the shape of a hoop.

The first step in the production system was flat filling. The inserts or pots were placed into the flat and filled with soil. The flats were filled and stacked next to the soil pile. One man could fill about 100 flats in an hour.

Our groundcover cuttings came from three different sources. In 1982, 23% of our groundcover cuttings came from stockbeds in the nursery. About 64% came from plants in production. The taking of cuttings from these plants also served as their pruning. The last 13% came from what we call cooperators. These were gardens or home landscapes in the area that had a large bed of groundcover. All of the cuttings were, and still are field made; that is they are cut, counted, stripped, and bundled together with a rubber band right in the field. As soon as one bundle is finished, it is immersed in a bucket of water and placed into a plastic bag in the shade. The cutting rate per hour varied with the type of cuttings and the source of the cuttings. If the cuttings were being made at a cooperator, the rate averaged between 5,000 and 10,000 cuttings per man per day. This was dependant on the amount of driving time to and from the cooperator, and the other maintenance work that was needed at the cooperator. When cuttings were made from stockbeds, the men averaged 15,000 to 22,000 cuttings/man/day. This was always a difficult job to do for it meant bending over for the entire day. If the cuttings were taken from production plants, the flats could be elevated to waist height and the average rate increased to 20,000 to 30,000/ man/day.

Periodically throughout the day, the propagator would pick up the bags of cuttings, bring them back to the work building and dip them in a Captan-Benlate solution. After draining, they were put back in the bags and placed in the cooler at 38°F. The hormone treatment would be done by the production crews just before the cuttings were to be stuck.

Sticking of the cuttings on the old system was for the most part done at a central location. A sticking table, which was shaded and protected from the elements, was located close to where the flats were setting. The workers stood at the table, stuck the cuttings, and then wheeled the flats, eleven at a time, to the frame where they were to be set. This system worked fine if the flats did not have to be wheeled very far. After setting the flats, they were lightly watered and covered with shade cloth or white plastic. The rate at which the cuttings were stuck was dependent on several factors: the crop, the size of the pot, and the distance the flats had to be wheeled. On the average one person could stick about 15,000 cuttings a day, which is

to say 7500 units per day could be produced because there are two cuttings per 2 and 3 in. pot.

The misting of the cuttings was controlled by time clocks. There were two different kinds of mist systems used. The *Euonymus* and *Pachysandra,* which went under shade cloth, were covered by a mistline that ran on the outside in between two frames. The nozzle was a shrub head irrigation nozzle which provided a coarse mist, and had an output of 3.8 gal/minute. This line doubled as an irrigation line when necessary. The *Polygonum,* which was stuck under white plastic, was covered by a mistline that ran down the center of the frame on the inside. These nozzles provided a very fine mist. Rooting of cuttings occurred in 4 to 6 weeks, and were ready to be moved out of the propagation frames soon thereafter.

After rooting, the propagation frames have to be cleared to get ready for the next crop. This was done by loading the flats of rooted cuttings on a trailer and hauling them up to the container division at the main nursery, 3 miles down the road. Since the container division did not have a permanent area set aside to receive the groundcovers from the propagation division, one of two things could happen to the newly-rooted plants. They may be placed in a prime area where they could be shaded for a while, properly watered and fertilized, and cared for in a proper way; or they could end up between 5-gal junipers with no shade, a watering regime set for the junipers and less than ideal conditions for the newly-rooted groundcovers. This latter situation became more prevalent late in the days of the old system. Also, at this time, hauling was getting to be a real chore. A crew of 3 men would be busy hauling 4 out of 6 days a week, from July 1 to September 15.

As mentioned above, in 1982 the annual production of groundcovers was about 1,100,000 units. Also mentioned was the fact that the propagation facility could handle about 310,000 units at a time, which meant about 3.6 rotations per year through each frame, (1,100,000 ÷ 310,000 = 3.6). Since each crop took 4 to 6 weeks to produce and the propagation season was about 4 months long (May 15 to Sept. 15), the facilities were just about adequate to take care of 1982's production. But, by 1984, when our annual production of these three items increased to 1,500,000, we needed 4.8 rotations through each propagation frame per year to make the schedule. Obviously this was impossible, so propagation ended up borrowing space from the container division to do its schedule. This put added stress on the container division, which was already overflowing with material that was hauled from propagation.

The significant increases in production caused several problems in the groundcover production system. Hauling was getting to be a sizeable job and of considerable cost, which really did not add any value to the product. Secondly, there was a lack of propagation space that was set up for groundcover propagation. Thirdly, the

rooted groundcovers were taking up more and more space in the container division which was affecting the production of 2- and 5-gal material. The system had to change. So it was decided to expand the propagation department by designing and building a new facility. It was decided that this new facility should be solely for propagation of groundcovers in flats, and should also function as a growing area. The goals of this new area were to achieve: increase groundcover production, improve quality and efficiency in groundcover production, and consolidate groundcover propagation and production into one area, thus opening up production space in the container division.

In designing the new system, two criteria were used for deciding how much land was needed. First of all, there had to be enough space to accommodate a yearly production of 2 to 3 million units, which we anticipated future production to be. Secondly, there had to be enough room to have a two year rotation. Since *Euonymus* and *Pachysandra* take a cycle of over a year to produce, having two phases and propagating in each section in alternate years, this would allow us to propagate, grow and sell each crop without ever having to move it. If a section was to lay empty for an extended period of time because of this cycle, we felt we could fill in with other short term crops. Fortunately, land was available adjacent to the main nursery and we were able to purchase 30 acres.

Construction started in August, 1984, and Phase I was to be ready in May, 1985. The first job was to have the land excavated and leveled until it had a 1% slope to the north and west. The excavator also dug a pond that would function as an emergency water supply and catch whatever run off there would be from the drain lines. The drain lines were the next to go in. One 4-in. drain line was to run between each house and connect to headers that would eventually lead to the pond. Following the drainlines, all inground irrigation and wiring were put in before winter; ¾ in. crushed limestone was tailgated over the entire area before any frames were built.

When the question of frame size came up it was decided to go with a larger 13 × 96 ft house rather than 6 × 40 ft frame. The larger house gave us greater utilization of space, fewer houses to maintain and cover; it could be covered by a standard 24 × 100 ft piece of plastic, and the combination irrigation-mistline could be located within the house. By having the mistline in the house, this would enable us to irrigate with the plastic on if ever necessary. It was also important to have each end of the house accessable by a road to facilitate the use of machinery.

The primary source of water for this nursery was to be a well that could supply 300 gal/min at 60 lb pressure. The water system was designed to be a pressurized system to permit misting the cuttings. A large pressure tank of 10,000 gal was installed to reduce the number of times the well pump would have to cycle. Double main

lines were installed and each ten-house section could be fed off either line. Since this new area was to be used as a propagation facility and a growing facility we felt it was necessary to have one line with clear water for misting the cuttings; the other line would contain fertilizer-treated water for irrigation of rooted plants.

The pH of the water from the well was 7.8 and we would prefer it to be down in the range of 6.3. So an Anderson Acid Injector was installed that would inject sulfuric acid into both main lines to reduce the pH. An inline pH meter was also installed that would constantly monitor the pH and have the ability to shut down the entire water system if the pH varied out of the set limits.

The fertilizing would be done by injecting liquid fertilizer into one of the main lines with a Volmatic Electronic Fertilizer Injector. The reasons we picked an electronic fertilizer injector over other systems were that it was capable of handling a wide range of flow rates, more versatile, easier to alter the stock solutions and, believe it or not, less expensive than other systems.

A soil mixing facility that could be operated efficiently was also to be part of this new construction. The four components of our soil mixes: peat moss, mushroom compost, perlite, and sand, were to be stored close to the mixing pad. Several bins capable of holding different mixes were also built adjacent to the mixing pad. Other things that were included in the building facility were a walk-in cooler, and under-roof storage for production materials and equipment.

Completion of this new propagation facility was on schedule and propagation of *Polygonum* started in May, 1985. With this new facility a new production system had to be developed that would accomplish the goals set forth before.

The flat-filling procedure was now to be a mechanized process instead of by hand. We hoped to increase the rate of flat filling, but also this was the first step toward mechanization. The machine would need a three-man crew to operate it, and a skid steer loader to load the soil into the hopper. As the flats come off the conveyor belt, they are stacked directly on a 5 × 10 ft self-tracking trailer. Once there are three trailers completed they would be hauled out by tractor to the site where the cuttings are to be stuck. The three-man crew would put the inserts in the flats and fill the flats with soil at a rate of 350 per hour, which is slightly faster than before.

The making of cuttings was basically the same system as before. We are still field-making all of the cuttings but the cutting rate increased because we are now taking more of our cuttings from production plants, and less from the cooperators. This is because we have a larger inventory of groundcover in production. The cutting rate on production plants averaged 20,000 to 30,000 cuttings per person per day while, at the cooperators it averaged only 5,000 to 10,000 per person per day.

The dipping of cuttings in the fungicide solution and hormone

treatment was about the same process as before, except that the new facilities are better able to handle the larger number of cuttings we are now dealing with.

All cuttings are to be stuck on site, now that it is possible to haul the flats to the sites by tractor and trailer. The flats are lightly watered to settle the soil and loaded onto hand carts. They are pulled into the houses and the cuttings are stuck in the flats right off the carts. Then the flats are set on the ground, and the operators work their way down the house setting the flats behind them. One house holds approximately 16,000 3 in. units, or 32,000 cuttings, and two persons can complete 1½ houses in one day.

Misting of the cuttings was basically the same procedure as before. Each house is controlled by a station on a time clock.

As mentioned before, growing-on of the groundcovers under the old system, was not always done by the book. But under the new system, proper attention could be given to this part of the production. As the crop is rooting the mist is gradually decreased until it is shut off altogether. The shade cloth or plastic is removed from the *Euonymus* and *Polygonum* while the *Pachysandra* remains under the shade at all times. Fertilization is begun when the first white roots consistantly appear on all of the cuttings checked. The first shot of fertilizer is given at the low rate of 150 ppm N. The second application of fertilizer comes about a week later and this would be at the higher rate of 300 ppm N. Pruning is not done until the second year when cuttings are taken to make the following year's crop. Weed control is generally not a problem, but we have done some tests with Devrinol and oxadiazon with good results. The use of insecticides is usually geared around the control of *Euonymus* scale on the *Euonymus* and oyster shell scale on the *Pachysandra*. We have found that preventative sprays of insecticide, especially during peak scale season, is the best way of controlling the pests.

This is really the last step in producing groundcovers. After two years of using this new system (1985 and 1986), we have looked back and evaluated whether we have achieved the goals we set out to. In 1984, the old system struggled and borrowed space to produce crops of 1,500,000 groundcover units. In 1986, the yearly production was 2,500,000 units, which is a 66% increase.

Another goal, which was achieved was to consolidate production of these three crops into one area. This opened up significant space in the container division for increases in the 2- and 5-gal production.

The third goal was to increase the efficiency of production and quality of these three crops. The flat filling rate under the old system was about 100 per person per hour; under the new system it was increased by 16%. There was an increase in the cutting rate because a higher percentage of the cuttings came from production plants which are faster to cut than from the cooperators or stockbeds.

Also, by having all the material in one area, the workers did not have to travel all over the nursery to get the cuttings. There was an increase in the sticking rate. Under the old system of sticking cuttings at a central point, on person could barely do 15,000 cuttings per day. With the new system of on-site sticking, one could consistantly stick 20,000 to 25,000 cuttings per day. We feel that the better growing procedures of slowly hardening off the cuttings, and giving them priority attention during the growing process will produce a higher quality plant.

In general, we feel we have achieved all the goals we set out to do when designing this new system but there is one more measurement that is needed. The cost accounting figures need to be compared between a crop produced on the old system with one on the new system; this will be the true test as to the success of the new system.

UPDATE OF GRO-PLUG® SYSTEM

THOMAS S. PINNEY, JR.

Evergreen Nursery Co. Inc.
Sturgeon Bay, Wisconsin 54235

Abstract. Most evergreen and deciduous plant material, whether seedling or cutting propagated, is being successfully integrated into our GRO-PLUG system. It has become a basic "Hub" and feeds directly into our second "Hub"—the SIX-PAC.

We reported on the practical application of GRO-PLUG systems for conifer ornamentals at the 1980 IPPS meeting (1). At the 1982 meeting, we reported on direct sticking of deciduous cuttings into the GRO-PLUG system (2). We have been asked to update our experience with GRO-PLUGS. Following are the major changes, expansions, and system philosophy that have taken place since the original two reports.

CHANGES

Conifer seedlings. We now find that all conifer seedlings we work with can be grown successfully as GRO-PLUGS. Fine tuning the system has made this possible. The system has become more and more complex—but more predictable. Complete scheduling is imperative.

Direct seeding. We have shifted from no direct seeding to almost 100% direct seeding. This required the development of our

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Direct seeding. We have shifted from no direct seeding to almost 100% direct seeding. This required the development of our

own direct seeding machines. They had to be cheap, simple, flexible, and reasonably fast! They had to sow *Thuja occidentalis* seed as well as *Abies concolor!* Such a machine was developed just for our needs and is constantly being revised. The machines are very portable and are set up in the greenhouse being filled.

It is essential that only seed lots with high viability be used. The seeds must be clean and all debris removed. This required the development of a sophisticated system of seed cleaning, testing, and storage.

Flat filling. The GRO-PLUG system uses a 73 cell groove tube jointly developed by Evergreen Nursery Co., Inc. and Growing Systems, Inc., 2950 N. Weil St., Milwaukee, Wisconsin 53212. Direct seeding speeded production to a point where it was necessary to modify our Gleason flat filler. The changes resulted in eliminating two people from the flat filling process.

Planting. Experience has shown that GRO-PLUGS may be planted in the field or containers as soon as field soil or containers are ready in the spring. In Sturgeon Bay, we try to complete the Evergreen Seedling GRO-PLUG (ESGP) planting into the field by June 15. Deciduous Softwood GRO-PLUGS (DSWGP) are completed by August 30, in the field. ESGP and DSWGP planting into containers is usually completed by August 15.

Automation of GRO-PLUG planting into containers. Since now all container-grown material starts with a GRO-PLUG, we can no longer effectively use hand planting. In cooperation with Gleason, a machine was developed to fill and drill SIX-PACS as well as 1- to 7-gal containers for planting with GRO-PLUGS.

Softwood GRO-PLUGS. Since first reported in 1982, we have modified the system considerably.

1) Fog (Agri-Tec) has replaced the mist system. (The droplets are not fine enough to be technically a true fog.) We have a flexible control system which can easily be switched for sunny, partly sunny, or cloudy conditions.
2) We have moved the propagation area to a 100 × 100 ft gutter connected structure. The house is covered by an inner layer of clear plastic with an outside opaque layer. Several crops are put through the house each season.
3) We now use a 50% shade lathhouse as a first step acclimation. DSWPG are then moved to full sun for a minimum of one week before transplanting.
4) The rooting medium has been modified by adding 25% perlite to the regular growing medium to insure adequate drainage.
5) Because of the high rooting percentage obtained, we now only stick one cutting per cell.

EXPANSIONS

GRO-PLUGS to SIX-PACS. As our containerized system evolved, it was apparent we needed a "second step" size container. The GRO-PLUG is 4.0 cm across at the top, tapered to 2.0 cm at the base, with a depth of 7.0 cm. The volume is 49 cm^3. Each plant has 21 cm^2 of space. The SIX-PAC was developed cooperatively with Keiding, Inc., 4545 W. Woolworth Ave., Milwaukee, Wisconsin 53218. These paper mache cells are 10.9 cm across the top, tapered to 7.0 cm at the base, with a depth of 12.5 cm. The volume is 709 cm^3. Each plant has 121 cm^2 of space, or approximately 6 times as much as in the GRO-PLUG. The SIX-PAC makes an excellent "second step" container. It can be planted even in the field through September. Root binding is not a significant problem with paper mache SIX-PACS. (Table 1).

Table 1. Comparison of various type plug containers used by Evergreen Nursery Co.

Type	Material	Manufacturer	Number grooves	Top diam. (cm)	Bottom diam. (cm)	Depth (cm)	Volume (cm^3)	Space/plant (cm^2)
GRO-PLUGS 73 cell	Polystyrene	Growing Systems	12	4.0	2.0	7.0	49	21
GRO-PLUGS 38 cell	Polystyrene	Growing Systems	4	5.5	2.0	12.5	138	36
12-PAC	Paper mache	Keiding	0	7.5	5.5	9.0	299	72
SIX-PAC	Paper mache	Keiding	0	10.0	7.0	12.5	709	121

[1] available 1987

Storage. As the system progressed, it was evident we needed to develop a cheap winter storage program. The GRO-PLUGS are properly acclimated, removed from the trays, and stored at 28°F over winter. This reduced the space required by approximately 90%. The plants are kept frozen until scheduled for planting the next spring.

Deciduous seedling GRO-PLUGS. The program has been expanded to cover deciduous items grown from seed, such as *Viburnum dentatum*. Seeds are germinated in small outside beds or given proper stratification and germinated in germination chambers. They are transplanted into the GRO-PLUG.

Micropropagated cutting GRO-PLUGS. Azaleas and rhododendrons are some of the items we propagated in microculture. The cuttings are removed, rooted, and transplanted into GRO-PLUGS.

38 Cell Groove Tube. After many years of development, Growing Systems will be introducing a 38 cell groove tube. In cer-

tain cases, such as with *Larix* and *Quercus*, larger "first step" tubes are necessary. The 38 cell tubes will have approximately 5.5 cm top diameter, tapered to 2.0 cm at the base, with a depth of 12.5 cm. The volume will be 138 cm^3 and each plant will have 36 cm^2 of space (Table 1).

12-PAC. In conjunction with Keiding, we have developed a 12-PAC designed as a "second step" for slower growing evergreens. Each cell is 7.5 cm at the top, tapered to 5.5 cm at the base. The depth is 9 cm. The volume is 299 cm^3, and each plant has 72 cm^2 of space (Table 1).

Evergreen cutting GRO-PLUGS. We presently are experimenting with direct sticking of evergreen cuttings into GRO-PLUGS. This is the last major area of our propagation system to be converted to plugs. Initial tests are very encouraging.

SYSTEM PHILOSOPHY

Inputs. The type of GRO-PLUGS in our system and the approximate 1986 production are listed in Table 2.

Hubs. Our two major hubs, GRO-PLUGS and SIX-PACS allow us great flexibility and act like airline hub cities, from which we can go in many directions (Table 3 and Table 4).

Shortening crop cycles. The GRO-PLUG/SIX-PAC system of containerized liners has effectively shortened the growing cycle of all of our crops. In the past for example, an 18 in. *Pinus mugo* ENCI required 8 to 9 years to grow a quality plant from seed. Now it requires 5 to 6 years.

Consistency. This system has added greatly to the consistency of the product. In many cases 50% of the grades within the crop have been eliminated.

Losses. Transplant losses have been reduced in the field from 30%, on a 10-year average, to less than 5%.

Flexibility. The system, with its "Hubs", allows a great deal of flexibility as markets change.

SUMMARY

The GRO-PLUG and SIX-PAC "Hubs" have become an integral part of our propagation system. It is a complex system, demanding high technology under the supervision of qualified personnel. Now a reasonably priced broad spectrum of containerized liners are available to the wholesale nursery trade.

Table 2. Inputs into 73 cell GRO-PLUG system.

Code	Description	Plants produced 1986[1]
ESGP	Evergreen seedling	1,060,000
BSGP	Birch seedling	460,000
DSWGP	Deciduous softwood cutting	250,000
DSGP	Deciduous seedling	20,000
ECGP	Evergreen cutting	10,000
	Total:	1,800,000

[1]Rounded to nearest 10,000

Table 3. Dispersal of plants from GRO-PLUG hub.

Crop	To container/field	Cycle[1]	Normal cycle
Direct Sales	73 cell GRO-PLUGS	1	—
Evergreen (fast growers)	SIX-PAC	2	4
Evergreen (slow growers)	12-PAC	2	4
Evergreen	1 gallon	3	4 to 5
Evergreen, once transplant	Field	3	4
Evergreen, once transplant select	Field	4	5
Deciduous	SIX-PAC	1	2
Deciduous (fast growers)	2 gallon	1	2
Deciduous, once transplant	Field	2	3
Birch, twice transplant	Field	1	3
Birch, 3 stem	4 gallon 3 to 4 ft	1	3
Birch, 3 stem	7 gallon 6 to 8 ft	2	4

[1]Total years includes time as GRO-PLUG

Table 4. Dispersal of plants from SIX-PAC hub.

Crop	To container/field	Normal cycle[1]	cycle
Direct Sales	SIX-PAC	2	—
Evergreen	2 gallon	3 to 4	5 to 6
Evergreen, twice transplants	Field	5 to 6	8 to 9
Deciduous (slow growers)	2 gallon	3	4
Deciduous (fast growers)	4 gallon	3	4

[1]Total years (includes time as GRO-PLUG and SIX-PAC)

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INTEGRATING FIELD AND CONTAINER PRODUCTION OF TREES

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Prior to the freeze of 1983, tree production at Greenleaf Nursery Co. was a containerized operation with the exception of the seed bed for some shade trees. Our propagation techniques were either by seed, grafting, or rooted cuttings.

Seeds were sown in the fall in raised ground beds, grown for one growing season and dug the following winter. They were healed-in outside storage beds of sawdust until March 15th when they were planted into 1-gal containers. That November the 1-gal trees were then shifted into 5 gal containers and grown for one more year to saleable size.

Grafts were made in January and February as bench grafts, allowed to callus, and then potted into peat pots and placed inside quonset houses heated to 50°F. This allowed the losses to occur in the less expensive propagation space instead of after planting in containers. The grafts were planted directly into 5-gal containers in May or June once they were actively growing. These grafts were then grown for 2 years in a 5-gal container.

A limited number of trees were grown on their own roots. A small number of 'Bradford' pear, all 'Red Sunset' maple, and 'Whitespire' and 'Heritage' birches were propagated by softwood cuttings. The cuttings were taken in late spring or early summer and stuck in ground beds in a quonset house. They remained in the propagation beds until spring when they were planted bareroot directly into 5-gal containers and grown for 2 years.

The severe winter damage we received on our container trees in 1983 prompted Greenleaf Nursery to purchase land in the Arkansas River bottom at Fort Gibson, Oklahoma, to be used for field production of trees. We wanted to keep the advantages of the containerized trees but still benefit from growing and overwintering our trees in the field. During that winter of 1983, we lost 10 to 100% of our grafted trees, depending on taxa and the type of 5-gal container they were grown in. We felt we could significantly reduce these tree losses from freeze damage by growing the trees the first year in the field and then transplanting them into containers the spring of their second and last growing season.

With our new system, we plant the graft, cuttings, or seedlings for budding in the field in early spring while they are still dormant. The grafts and cuttings grow for one year and are dug the following February after going through the winter in the ground, giving the roots more protection than they would have received in a container.

These year-old trees are then planted into 5-gal containers and grown one more growing season and sold in the fall or the following spring. Since the trees grown from seed were not as severely damaged by the cold, only 5 to 30% killed, they remain on the 1983 production cycle except they are shifted from #1's to #5's in the spring instead of the fall.

The results of this change to the field for the first year of the 2-year growing cycle not only improved our winter survivability but also afforded us the opportunity to improve on other problem areas in our tree production.

In the area of propagation we have continued previous techniques that were effective but have been able to add better methods on problem plants. Named cultivars of redbud have an incompatibility problem when they are grafted. By going to the field operation, we can bud the redbud cultivars and get a better take—65 to 75% compared to 30 to 50% for grafting. Not only does our percentage increase, but budding costs are $25/100 less than grafting costs. Budding was not a viable option in the container operation because it would add an extra year in the container to the program at the expense of valuable space. Budding has also increased our stand of 'Aristocrat' pear. In the past, during the grafting procedure we would develop a bacterial disease, cause by *Pseudomonas*, which would kill the scion. By changing to budding of 'Aristocrat' pears we have improved our survival rate from 20–70% to 80%.

Another problem that the change to the field production overcame was the death of grafts when they were transplanted from the propagation bed to the 5-gal container. Since the grafts needed to be actively growing when they were planted, their planting in June correlated with the onset of hot weather in Oklahoma. We would lose anywhere from 5 to 30% of the grafts to heat stress, depending on the type of summer we had. By going directly to the field from propagation, the grafts are dormant when planted in February and so are well established before summer arrives.

Other improvements to our system are being investigated. In the propagation area we are refining our procedure for rooting trees such as 'Bradford' pear, cherries, crabapples, and maples. Even though we can root these trees, we do not increase the number we propagate until we evaluate the hardiness of the own root vs. grafted trees.

In the case of 'Bradford' pears and 'Red Sunset' maples, there was no difference in the hardiness of own-root vs. grafted through the winter of 1983. The other plants we root remain to be tested for hardiness before they go into full production. We are presently propagating ⅓ of our 'Bradford' pears by softwood cuttings and because of the interest in this procedure I will briefly summarize our method. 'Bradford' pear cuttings are taken in early June just as the new growth begins to harden and the leaves begin to change from

light green to dark green. The 6 in. cuttings are stripped of their lower leaves, dipped in a Captan/Benlate fungicide solution and then given a quick dip in a 10,000 ppm IBA + 5,000 ppm NAA hormone solution. The cuttings are then stuck in ground beds of pine bark/sand (1:1, v/v) under intermittent mist for 10 seconds every 12 min. during the day. The pear cuttings callus and initiate roots in 6 to 8 weeks. Just as the cuttings start to root, the leaves begin to turn black. At this point, the mist needs to be reduced to 10 seconds every 30 min. and then stopped within 7 days. All the cuttings will not be rooted but if the medium is kept moist and the plants are shaded, they will continue to root.

We have also started a tissue culture lab to allow us to get into new tree cultivars faster, to propagate hard-to-root or hard-to-graft types and to eliminate diseases. We are experimenting with 'Aristocrat' pear and purple leaf smoke tree with limited success.

Finally, we are experimenting with different types of 5-gal containers and how best to overwinter these containers. In the winter of 1983 we had 'Bradford' pear in two container types, round green metal 5 gal and round black plastic 5 gal. Ninety to 100% of the pears in the round black plastic 5 gal were killed, whereas only 10 to 15% of the pears in the round, green metal cans died. To date we can only theorize why. We think one of the major differences between the two types of containers is the shape, straight sides vs. tapered sides. The metal cans are straight sided so when they are placed can-to-can for winter, little air can penetrate through the bed of cans. The plastic containers are tapered so when they are placed can-to-can, air can easily move among the cans in the bed; thus, losing the insulation factor which is the purpose of bunching can-to-can. To overcome this problem we have gone to square plastic cans that are straight sided for at least the top 3 in. and then tapered very gradually. We need another severe winter to prove the benefit of these cans.

Secondly, we think the material the containers are made of and the color of the containers plays a role in winter protection. The black plastic containers absorb heat better than the green metal cans; thus, keeping the roots actively growing later in the fall and start them growing earlier in the spring. Therefore, the root systems are more susceptible to early and late freezes. The metal cans are better conductors of heat and cold than the plastic containers. We feel that the metal cans conduct the cold to the root ball allowing the roots to harden earlier. But, we also wonder if the metal cans do not conduct ground heat up to the root ball once the plants are bunched can-tight and strawed in.

Finally, we are placing the containers can-to-can but staggering the rows to form a wind barrier past the second row of cans. In 1983, our procedure for overwintering trees was to bunch the containers can-tight in straight rows then straw around the top and sides of the

bed of trees. In a normal winter straw proved to be a very beneficial insulator. However, in 1983 the cold spell was so long, 15 days below freezing, that the entire root ball froze even under the straw. At that point we feel the straw became detrimental because it did not allow the root ball to thaw as rapidly once the temperature did go above 32°F. Therefore, this year we are testing trees in all three types of containers, square plastic, round plastic and round metal, can-to-can under 3 straw regimes; 1) no straw, 2) straw only on the sides of beds, and 3) straw on top of the containers as well as the sides of the bed. We are recording temperatures in these containers to try and correlate temperature conditions to any possible freeze damage. Unfortunately, to achieve good results, we need an extremely cold winter.

To summarize our new tree production we are:

1) Propagating by seeds, grafting, softwood cuttings, budding, or experimentally by tissue culture.
2) Planting dormant bareroot liners into the field in early spring.
3) Growing and overwintering the trees the first year in the field instead of in containers.
4) Transplanting the one-year-old trees bareroot into 5 gal containers in the spring for sale the following fall or spring which allows for only one winter in the container at most.
5) Constantly evaluating and improving our overwintering practices for the two-year trees by evaluating container types as well as the manner in which the containers are treated for winter.

The primary reasons we made these changes were:

1) To reduce the number of winters the trees are in containers from two to one, thus cutting down our potential overwintering losses.
2) To improve the percent saleability and quality of 5-gal trees. By growing larger numbers of each kind of tree in the field, which is a less expensive production method, we can cull heavily for quality before the trees go to 5 gal containers.
3) To allow us, through grafting and budding, to greatly diversify the cultivars of trees we grow.

INFLUENCE OF CONTAINER CONFIGURATION ON MEDIUM TEMPERATURES IN OVERWINTERING STRUCTURES

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Abstract. Medium temperatures and between pot air temperatures were measured within blocks of closely packed round and hexagonal #1 nursery containers inside of a white polyethylene covered, unheated overwintering storage house at John Vermeulen & Son, Inc. Nursery in Neshanic Station, NJ. Temperatures were recorded every 2 hours from November, 1984 through June, 1985. During the period of November, 1984 through March, 1985, little consistent difference was seen among pot types along the wall of the house and along the aisle. In the center of the block, however, hex pots showed average temperatures and minimum temperatures that tended to be in the range of 0.5 to 1.5°F warmer than round pots in similar locations. Within each pot type, there were differences associated with pot location within the block and with thermocouple location within the pots at the various locations.

J. P. Vermeulen: Plant culture in special containers at our nursery has been a practice for over 25 years. We have run the gamut of available containers from the original punched, crimped, and asphalted reclaimed fruit and vegetable cans to the present abundance of specially manufactured styles, sizes, and configurations.

In 1983 we started testing a No. 1 (formerly industry 1 gal) 6 sided container that measures 6 in. across and 6 in. deep. Our standard at that time was the regular round 1 gallon that is 6 in. in diameter and 7 in. deep. The containers were potted at various times during the growing season and placed in quonset style growing houses. The houses are covered with 49% shade polypropylene netting from approximately June 1 through October 1 and with white polyfilm sheeting from approximately November 1 to April 1. This is not a fixed time frame and actually fluctuates with weather conditions. The houses are not heated and are 15 ft wide by 120 and 140 ft long, and 7 ft and 9 ft high at center. They are oriented east/west.

Our climatic Zone is USDA 6A, but we experience a microclimate of 5A. Our temperatures range from extremes of −23 to 101°F with a mean of just about 50°F. We average 190 growing days, with the first fall frost as early as mid-September (this year we dipped to 32°F on the morning of August 29) and our last spring frost in mid-May, the latest being June 10.

Because of our microclimate we are much concerned with medium temperatures in our growing containers. Our usual checks

seemed to indicate 5 to 10°F higher winter medium temperatures in the new 6-sided container than in the regular round No. 1. This prompted a desire for more accurate data and the research you are about to hear reported. The research was conducted at our nursery by Dr. Arthur Vrecenak, Assistant Research Professor at Cook College, Rutgers University. We are much impressed with Art's data and analysis. Since he is so much more conversant with and qualified to report the data and findings than I am, I sought and have permission to have him do so. At this time I am pleased to introduce him to you, Arthur Vrecenak.

Arthur Vrecenak: Thank you, Pete, for the kind introduction. It is a pleasure for me to be here today to speak to you. My colleague, Dr. Elwin Orton, has always spoken very highly of this organization, and I welcomed the opportunity to present my work when it was offered.

INTRODUCTION

The use of containers in the production of woody plant materials has added many benefits to the nursery industry, including ease of handling, an expanded marketing and planting season, greater production per unit area, and faster production cycles. It has also added some of its own unique problems to nursery management in the U.S. Northeast. One of these problems involves the overwintering of this plant material. The fact that root tissues do not develop the same degree of cold hardiness as do stem tissues (1, 2) and that young roots differ from mature roots in their ability to develop cold hardiness (2) presents another set of circumstances that must be managed at the nursery.

There are plant species and/or cultivars that can be difficult to overwinter successfully in the standard unheated polyethylene quonset storage house. The reasons for this are not always obvious, but often are related to the root cold hardiness characteristics of the plant material. When grown in the field, root tissues are well buffered against the temperature variation experienced by the stem tissues. The roots of container-grown plants are not so well protected and the more tender roots are exposed to greater temperature extremes and fluctuations than they would encounter in the field. In order to enhance survival and growth of these materials in this artificial environment, it is important both to understand and to properly manage that environment toward those ends.

OBJECTIVES

The objectives of this work were:

1) To determine the validity of the assumption that closely packed hexagonal nursery containers would be better able to utilize the thermal buffering effects of the soil beneath

them to moderate temperature extremes than would closely packed round containers of similar size.

2) To compare temperature responses within the medium at the edge and center of each pot.
3) To compare the temperature responses of pots at three location within each block.
4) To compare the temperature responses within the air spaces between pots for each pot type.

MATERIALS AND METHODS

As mentioned, the measurements were taken at John Vermeulen & Son, Inc. Measurements were taken every 2 hours, except during a 2-hour period bracketing sunrise and sunset, when 20 min intervals were used. The thermocouples were placed in pots on the north side of the house. For each pot type, one pot was located on the aisle, one was in the center of the block, and one was along the wall. Within each pot, one thermocouple was placed 2-in. deep in the center of the pot and one was placed 4-in. deep and 0.5 in. in from the north edge of the pot. Inside and outside air temperature measurements were taken using shielded thermocouples on wooden stakes at a height of 4 ft. Between pot air temperatures were measured by suspending a thermocouple between pots at a depth of 4 in. from the rim of the pot. All data was recorded on a Campbell Scientific 21× microprocessor-based datalogger.

RESULTS

Table 1 is a summary of the data for a randomly selected day (January 24, 1985). For each location within the block, no substantial difference in average temperature was seen between the two pot types. On this particular day, a slight difference of 0.6°F was seen between pot types in the middle of the block, but this was not a consistent trend. Minimum temperatures, however, tended to be approximately 0.5 to 1.0°F higher in hex pots than in round pots over the course of a day.

Table 1. Averages, minima and ranges of temperatures (°F) for the various thermocouple locations on day 24.

	Wall		Middle		Aisle		Between
	Edge	Center	Edge	Center	Edge	Center	Pots
Hex avg.[1]	28.8	28.6	30.8	30.3	29.3	29.4	31.4
Hex min.	25.5	24.5	29.5	28.3	25.4	25.7	30.7
Range	5.8	7.2	2.1	3.4	6.3	5.9	1.2
Rnd avg.	28.6	28.4	30.2	29.7	29.5	29.1	30.3
Rnd min.	24.9	24.2	28.7	27.1	26.5	25.3	28.4
Range	6.5	7.4	2.8	4.6	5.0	6.3	3.2

[1] Hex = 6 sided pot, Rnd = round pot.

For the mid-winter to early spring period, when outside temperatures were low, average pot temperatures were lowest along the wall for both pot types. Medium temperatures in the center of the block tended to be higher and to fluctuate less than those of either the wall or the aisle location. The data in Table 1 are representative of the period in this respect.

Within each individual pot, edge temperatures tended to vary less than the center temperatures, except in the hex pots along the aisle, where edge and center temperatures consistently showed very similar responses.

The air temperature between hex pots in the center of the block tended to be less responsive to fluctuations of inside air temperature compared to round pots. This comparison was not made on the aisle or along the wall due to equipment limitations.

Table 2 lists the minimum temperatures reached and its date of occurrence for each measurement location during the entire study period. Those pots located along the wall showed the most extreme minima, and the center location in the pot reached a lower temperature than did the edge. The pots along the aisle tended to show slightly less extreme minima, and the pots in the center of the block were least affected by extreme minimum tempteratures. Once again, with the exception of the hex pots on the aisle, the center locations reached lower minima than did the edge locations.

Table 2. Seasonal minima for the various thermocouple locations.

Location	Date	Temperature (°F)
Hex wall, E[1]	Jan 21	18.7
Hex wall, C	Jan 21	16.9
Rnd wall, E	Jan 21	18.4
Rnd wall, C	Jan 21	17.0
Hex mid, E	Jan 22	28.4
Hex mid, C	Jan 22	26.8
Rnd mid, E	Jan 22	27.5
Rnd mid, C	Jan 22	25.4
Hex aisle, E	Jan 21	19.2
Hex aisle, C	Jan 21	19.9
Rnd aisle, E	Jan 21	21.8
Rnd aisle, C	Jan 22	21.4
Hex air	Jan 22	30.0
Rnd air	Jan 28	27.3
Outside	Feb 4	− 6.2
Inside	Jan 21	15.2

[1] *Hex = 6 sided pot, Rnd = round pot.*

DISCUSSION

There may be a thermal benefit to the use of hexagonal pots if one considers the effect of pot configuration on the minimum temperature reached by the medium in the pots. The fact that hex

pots tended to have higher minima than did round pots might be justificaton for their use in some cases. Further work needs to be done to assess the potential benefits of this phenomenon.

Temperatures in the center of a pot tended to fluctuate more than temperatures along the edge, probably due to the relative stability of the between pot air temperatures compared to the ambient house temperatures. Figures 1, 2, and 3 show the temperature responses of the various thermocouple placements within the pots to an increase in outside and inside air temperatures from approximately 0700 to 1400 hours on 24 January 1985. For all locations within the block, temperatures in the pot centers responded more readily to a change in ambient air temperature than did the temperatures along the pot edges, as evidenced by the steeper slopes of the lines corresponding to the center thermocouples in all three figures. The differences are most pronounced in the mid-block location, since the edges of the pots would be most thermally buffered from the effects of lateral intrusion of ambient air. The edges of these pots are responding primarily to the fluctuations of the between-pot air temperatures, which Figure 4 shows to be quite negligible. The primary location of heat exchange in the mid-block location is from the surface of the medium, which is exposed to the ambient air within the house. Over the course of this day, the ambient air showed a range of approximately 17°F, while the between pot air temperatures fluctuated approximately 1 and 3°F for the hex and round pots, respectively.

This is the difference between the hex and round pots that led to this study. The air temperatures between hex pots fluctuated less than did those between round pots. Whether the corresponding medium temperature responses shown in the data of this study differ significantly is a question that needs to be answered by a controlled study. And even if a statistically significant difference can be demonstrated, is the difference significant to winter survival? These questions cannot be answered here, but we do have some information that suggests the merit of additional work.

It is worth noting in Figures 1, 2, and 3 that the mid-block pots showed less response to ambient temperature fluctuations than did the other two pot locations. The elimination of these extremes might be beneficial to winter survival, since plants respond to temperatures as they move through the various levels of hardiness during the cold season. It seems reasonable to assume that the closer we come to simulating the natural temperature conditions in the field, the better our chances of increasing winter survival of container plant material.

This would lead me to guess that the tests being conducted by the previous speaker should show that complete coverage of the block of plants by some sort of mulch material would be most advantageous. The reduction in the lateral exchange of heat would

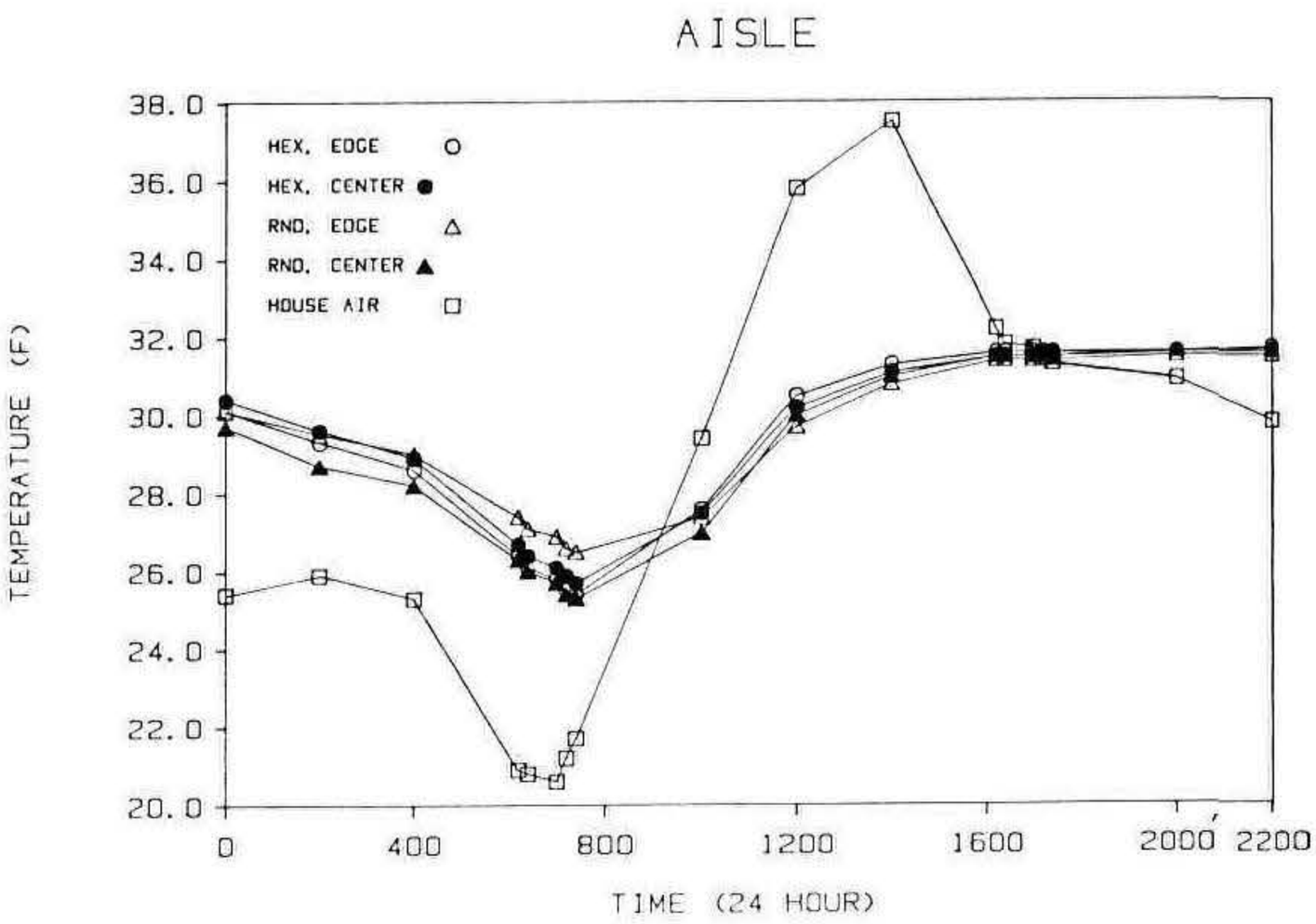

Figure 1. Medium temperature responses of the two locations within the two pot types to the ambient air temperature in the aisle location on day 24 (24 January 1985). Hex = 6 sided pot, Rnd = round pot.

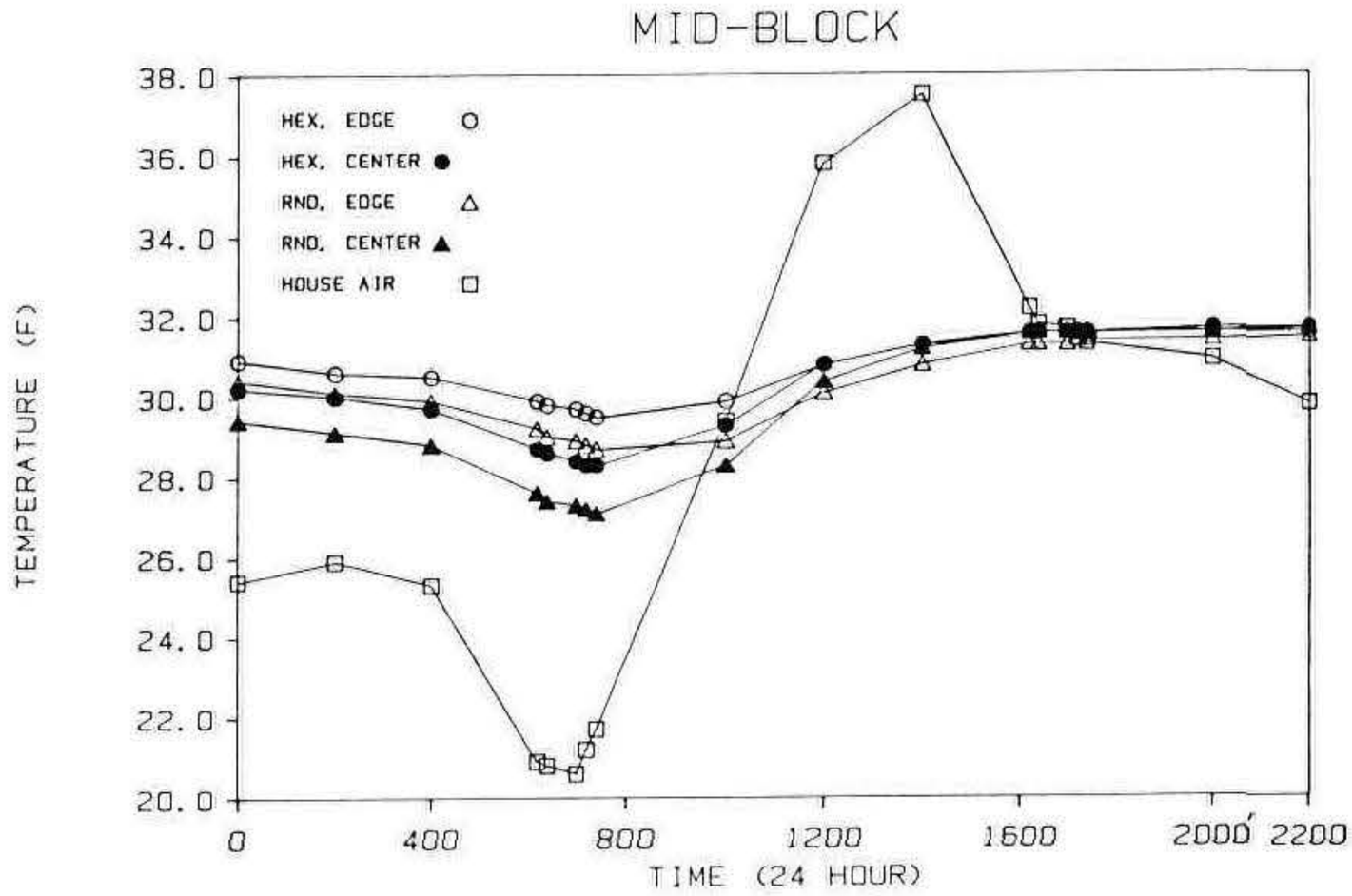

Figure 2. Medium temperature responses of the two locations within the two pot types to the ambient air temperature in the mid-block location on day 24 (24 January 1985). Hex = 6 sided, Rnd = round pot.

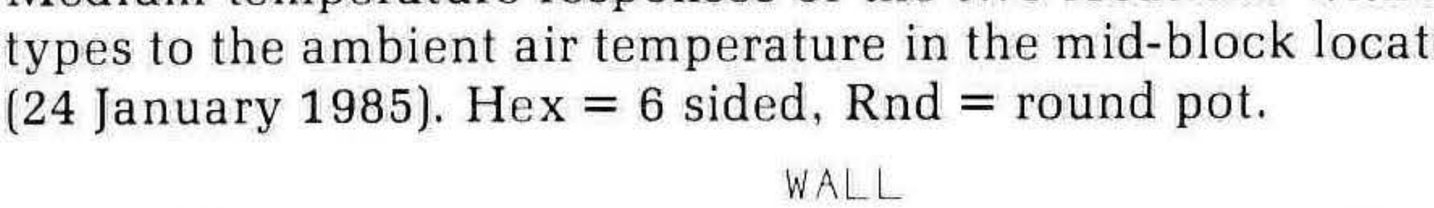

Figure 3. Medium temperature responses of the two locations within the two pot types to the ambient air temperature in the wall location on day 24 (24 January 1985). Hex = 6 sided pot, Rnd = round pot.

allow more of the block to respond like the pots in the mid-block location of this study. Covering the surface of the pots would reduce the exchange of heat from the surface of the soil medium, allowing a greater proportion of the volume of the pot to respond like edges of the pots in this study.

More work needs to be done and will be done to study the responses of containers to cold temperatures. We hope that further tests under controlled conditions can lead to more answers about how to successfully overwinter container plant material.

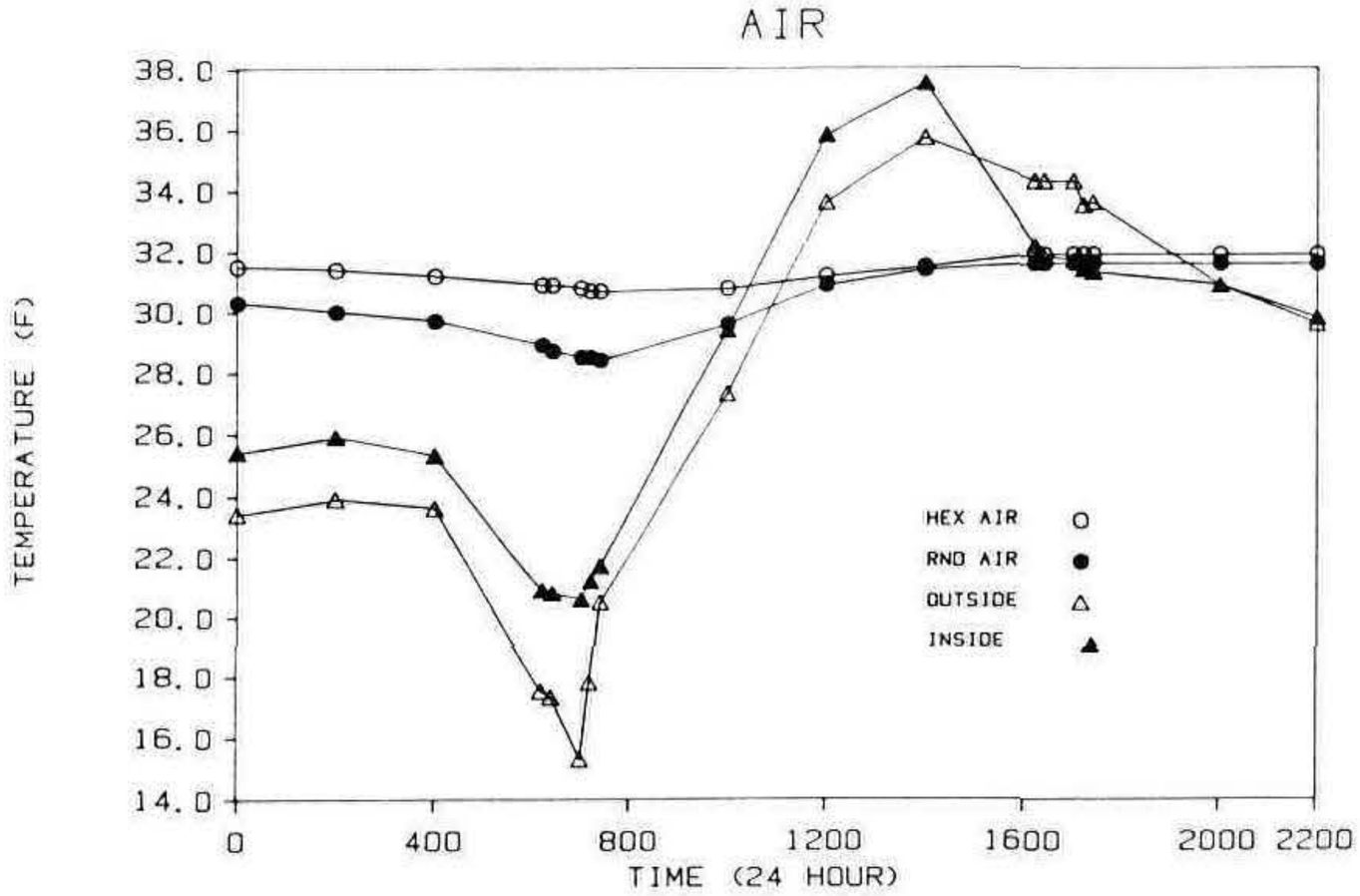

Figure 4. Response of the between pot air temperatures for the two pot types to the ambient air temperature in the mid-block location on day 24 (24 January 1985). Hex = 6 sided pot, Rnd = round pot.

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ECONOMICS IN PROPAGATION—A KEY TO HORTICULTURAL SURVIVAL

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It has been 14 years since I last spoke before this Society. At that time I was 27, full of ambition and naive idealism. I was part of a symposium discussing the production aspects of hybrid rhododendron production and was beginning to formulate the plans for restructuring and moving our company. Very little thought was given to the future economic policies of companies in our capitalist system; I was aware of the historical view and felt that the future was relatively secure. As I mentioned, I was very naive.

The last 14 years have been very turbulent; our economy has experienced a series of "crises", both real and imagined. There have been problems with energy in production, distribution, and availability. There have been rapid and rather severe "boom and bust" cycles in the economy; at one point the experience has been severe double-digit inflation with high interest rates, followed by severe deflation with an accompanying drop in rates. Consumer demand for goods has been erratic at best and very hard to judge. Long time standards used in the business world for stable projections of future business needs have either changed or been eliminated in very rapid fashion, making projections very difficult. The financial community has been especially erratic; the key here has been to find a financial institution that understands the needs of a modern horticultural business and allows flexibility in financing. The key word, especially for the last 6 years, has indeed been "survival".

Many may ask, "What on earth does this have to do with propagation? Unfortunately, many businesses have failed or will fail in the future because there is not a clear understanding of the economic process involved in plant production of which propagation is a very integral part. To help in understanding this process, economics should be concisely defined. During some of my research for this paper I came across an interesting and very valid definition of economics. "Economics is concerned with the efficient utilization or management of limited resources for the purpose of attaining the maximum satisfaction of human material wants" (1).

If this definition is carefully examined, one realises that many companies in the horticultural field do not understand this concept; the business policies followed eventually doom them, at the least, to gross inefficiency, or at the worst to outright failure. I can relate to this problem as our company faced this concern about 6 years ago.

This was an extremely humbling experience and was brought about by the advent of our original computer system. I was keenly aware of the substantial capability for the system to process accounting information and allow us to begin to forcast for the future. With the help of some outside programming in addition to our initial purchased software I began to project ahead. The shock was great! Based on historical reference for sales and company expense and plugging in analysis information for future sales trends up to 3 years in advance, our company was going bankrupt by 1984. It was obvious that something was very wrong.

Challenge has been a large part of my life; I have learned a great deal from it. This looming situation was no exception. I have coined a corny phrase that helps me through tough times: "Ignorance is the next best thing to intelligence." The inference here is that if a situation is analysed without preconceived ideas there is usually a clear solution. In this case I began to realize that our whole economic structure was incorrect and had to be changed rapidly. My first priority was to gather information specific to horticultural need.

You can imagine my surprise when I found a void of available information. Either we were not considered a viable industry or those in the know were not telling. Thus, my only alternative was to turn in another direction. At this time I began to follow a policy that I maintain to this day; I consider our company an entity manufacturing a product for sale, nothing more and nothing less. Instead of trying to gather information within our field I gathered information about manufacturing in general. For profitable production of any item I came up with a series of simple yes/no questions:

1) Is there a demand for your intended product?
2) Is the demand for your intended product exceeded by present supply?
3) Are there adequate raw materials for the production of your intended product.
4) Can your intended product be properly distributed for resale?
5) Is there extensive competition for the production of your intended product?
6) Can you be cost-efficient in the production process?
7) Does a marketing plan exist for your intended product?
8) Does your intended product have an effective production life cycle beyond which profit will no longer be obtained?

By using simple yes/no questions I was able to build an objective picture as to how to begin a change in our production emphasis. Most certainly marketing concepts came into the situation. Briefly, we established a marketing concept that was to promote our product

to the maximum number of people. We examined all the procedures followed by our competition and formulated all the quality control and service control policies needed to be successful. One key issue was our price structure, especially in relation to prices being set in the marketplace by our competition for a comparable product. In order to set a profitable price one had to know the final cost of production.

There has been much discussion as to how to determine cost of a product. Relationships have been made to direct labor costs as a specific percentage of final costs; other procedures have carefully itemized each direct cost to a specific operation, such as the propagation procedure. After carefully studying all available information I came up with a procedure that was extremely beneficial to us. I call it the "loaded cost" factor for all of our production needs. Many years ago we decided that we could maintain better quality control of our production if we could maintain a full-time, year-round labor force. The idea was to allow this labor force to be involved in all of the jobs necessary for the propagation and production of the crop. Our staff became multi-skilled and flexible in all areas. By spreading out the peaks and valleys of the expense we became a true manufacturing unit with stabilized monthly costs for production.

As we now had to maintain our production facility at higher operating levels for the winter months and lower levels for the growing season period we found that blending of expense occurred during the production cycle. Thus, I developed the total dollar amount needed for the company to operate at a break even situation for one complete year. *Every* known expense was factored, and this gave us a base amount of inventory to sell in numbers, based on existing selling price. As our expense system was computerized I had a weekly check as to total expense figures during any specific work situation. These figures were tabulated every month into a cash flow statement for expense. If necessary, we could cross reference our cash flow statement with our weekly work journals to determine more precise accounting. This is exactly what took place in the propagation area. Our cost of propagation was accurately determined based on use of materials, labor, cost of unrooted cutting, the loaded cost factor needed to keep the business doors open, and the cost of propagation loss. We then had complete expense factor for a surviving rooted cutting. This expense factor is called our cost of propagation. From this point we could then follow the same procedure for all sizes of plants in our production system. Each time we determined our total "loaded" cost; this was the amount of money necessary needed to satisfy all financial requirements to keep the business at a break even point. Every size plant was calculated so that appropriate production levels could be determined.

At this point it was necessary to divert our analysis into three different directions. First was a market analysis to determine exactly where the voids existed in the marketplace as to quality product, quantities, sizes and service orientation. Once this was completed we could then analyze our production facility as to changes needed to satisfy the market analysis. Finally, once the production needs were determined, the propagation facility could be analysed and reorganized in order to satisfy the production needs. Briefly, we found that we could supply the voids by ruthlessly eliminating certain sizes of plants due to extreme competition and start to grow different sizes not available at that time. This allowed for tremendous expansion within the existing facility. At the same time tests were undertaken to formulate a similar plan in the propagation area. The net result was we were able to increase propagation by 70% in the existing area, thereby lowering cost. Production increased by 200% in the same existing area; lower costs carried forward allowed for purchase of material either as liners or semi-finished plants to grow on at a profit.

The process just described took 4 years to complete. I followed a very simple step by step process:

1) Recognize the problem.
2) Compile all available information needed in unbiased manner.
3) Determine dollar income to satisfy break-even point.
4) Extrapolate break-even dollar income into inventory requirement based on existing pricing.
5) Accurately determine cost of product starting with propagation and carry through entire inventory level.
6) Establish market analysis for product line and develop marketing strategy accordingly.
7) Maintain accurate records and continue market analysis and strategy for future needs.

I cannot be more firm in emphasising the importance of marketing strategy in business survival. One of the main keys to our continued success and profitability has been a keen application of marketing principles tied with accurate cost accounting. At the beginning of this 6-year period our company was in low six-figure income and facing extinction. By proper application of standard manufacturing principles in marketing and accounting we are presently in seven-figure income holding future signed purchase order contracts for 3 years hence. Our net profitability has increased substantially and we project that it will continue to do so if a vigilant eye is kept to total market analysis. It is a concept of "back to basics", which I feel is an integral part of this Society and should be

of every horticultural enterprise that wishes to survive and succeed in the future.

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STICKING *TAXUS* AS UNSTRIPPED CUTTINGS, AN UPDATE

MARK RICHEY

John Zelenka Evergreen Nursery
Grand Haven, Michigan 49417

The following is an update on how we are processing and handling *Taxus* cuttings at Zelenka Nursery.

At the Grand Rapids IPPS meeting in 1982, you saw approximately ½ of our Taxus crop stuck as unstripped cuttings and the balance stuck traditionally as stripped cuttings. We talked about the reasons and what we had found out to that point on the tour. We have refined our process to balance labor efficiency with rooting efficiency.

The early 1980's saw an imbalance in growth. Production was increasing faster than sales, so we were looking at ways to reduce labor while keeping our quality up. In November 1980, an R&D project was initiated to stick 5,000 cuttings of two *Taxus* cultivars as unstripped cuttings. The goal was to decrease the cost per cutting by $0.001 cents, while not reducing quality. That first year's experiment was successful, so we increased it in 1981 to 5,000 cuttings of 4 *Taxus* cultivars. This showed even more favorable results. We not only received a labor savings, but we saw a better rooting percentage on the unstripped than on the stripped cuttings. This prompted us to stick ½ of the crop in 1982 as unstripped. After evaluating that crop, we decided that all cultivars, except *T. cuspidata* 'Densiformis', would be stuck unstripped.

Let me regress a moment, to explain how we were processing the cuttings. They were taken by hand off 5-year liners in the fields. Terminal and basal ends were cut (leaving the cutting 6 in. long), hormone-treated, and stuck in the benches with bottom heat. The only difference was that the stripping action was eliminated. This was a significant decision, not only because of labor savings, but from an insurance point of view. We had several medical cases of "Carpal Tunnel Syndrome" that had been associated with clipper usage and the stripping action.

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Enthusiasm over the successes of this project prompted us to carry it further. In 1982, we tried harvesting cuttings with a modified combine. That proved successful in labor savings. So in 1983, we increased the magnitude of our test. By 1984 we were taking as many cuttings by machine as possible. Limiting factors were shortages of stock plants and some cultivars that were not compatible with combine harvesting.

We were still making changes in the preparation room. Since we were still having too many "Carpal Tunnel" cases, we were advised to look at alternative methods of making cuttings without clippers. We ended up putting the cuttings into bundles as they came out of the crate, cutting the basal ends of the bundles with a band saw, standing the bundles upright in blueberry lugs, and cutting the tops even with an electric hedge trimmer. The lugs were dipped into sinks of hormone and then stuck in the propagation bench. Our increased labor efficiency culminated with last year's crop of 2.1 million cuttings processed and stuck in 10 days. However, speed is not everything and refinements have to be made. Some problems have to be worked out to increase quality and minimize risk.

Obviously, the faster an operation is, a greater chance of carelessness exists. Two things we had to watch were the cuttings drying out and/or heating up. Because the combines were harvesting the cuttings faster than we could haul them to the cooler, the tendency was to stack too many bags on a pickup. Then to make room in the cooler the bags were stacked as high as possible. The pressure on the bottom bags caused the cuttings to heat up and start molding. The bags required an extra handling step, so we started putting cuttings directly in bulk crates. This made unloading the cuttings into the cooler and bringing them out again much easier with a forklift. It was also a means of stacking the cuttings to the ceiling without putting pressure on the bottom of the stack. The cuttings we hand cut were also dumped into bulk crates in the field and handled the same way. The biggest drawback to this was desiccation. Each truck had two bulk crates on it which took the cutting crew 2 hours to fill. The crates were covered with white poly for transport. The cooler was kept at 85 to 90% humidity with a Baanson humidifier and the temperature was set at 35°F. After all the cuttings were taken from the field, the preparation and sticking began.

Our standard cutting length was 6 in. By making the cuttings in mass, uniformity of cutting length suffered. Branched cuttings were going through the process without getting trimmed as well, and that caused nonuniform sticking density in the benches. At times, if the person operating the hedge trimmer tried to speed up, the bundles would pull out of the lug and be cut shorter than the desired 6 in. Quite by accident we found out that 4-in. cuttings rooted as well as the standard 6-in. cuttings. This gave us second cuttings out of leads that would have yielded only one and it increased air flow around

the cutting at bench level as if the density had been decreased.

Most of the cultivars rooted better as unstripped cuttings, when all the conditions were the same. I mentioned earlier that all cultivars except *T.* 'Densiformis' were stuck unstripped. We kept trying *different variables and finally found that decreasing the hormone* level from that of our normal program for *T.* 'Densiformis' brought the rooting percentage back up to our previous level.

Sticking the cuttings has been a little slower but not enough to change our rates. It has been trickier to space the cuttings more evenly and it takes a lot more supervision to be sure the depth of sticking is consistent.

In summary, about 10% of this year's crop was harvested with a machine, due primarily to a shortage of cutting wood. We are sticking all cultivars as unstripped 4-in. cuttings. We are still working on perfecting the band saw and hedge trimmer method but this year it will remain R&D. The cuttings will be made individually, screening out the branched cuttings that will require stripping. Hormone treatment will be done by bundle instead of lug and the sticking will be paced to finish in 15 days.

STOCKPLANT ETIOLATION AND BANDING FOR SOFTWOOD CUTTING PROPAGATION: WORKING TOWARDS *COMMERCIAL APPLICATION*

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Abstract. The technique of stockplant etiolation has made it possible to root cuttings of plants which previously could only be propagated by budding or grown from seed. The cost of producing rooted cuttings from etiolated stockplants is approximately $0.05 to 0.10 more per cutting than traditional cutting procedures. The practice of field etiolation can produce a finished plant in the same time as field budding. Greenhouse etiolation substantially decreases the time required to produce a finished plant.

REVIEW OF BASIC TECHNIQUE

The technique of etiolating stockplants prior to cutting propagation has been shown to yield markedly improved rooting percentages for plants previously considered difficult-to-root (1). Etiolation means growing plants in the absence of light or in very heavy shade as the term is commonly used in cutting propagation. The basic method involves covering dormant stockplants with black shade cloth when the buds are beginning to swell. Typically, greater than 90% shade is used because it is not necessary to achieve

the cutting at bench level as if the density had been decreased.

Most of the cultivars rooted better as unstripped cuttings, when all the conditions were the same. I mentioned earlier that all cultivars except *T.* 'Densiformis' were stuck unstripped. We kept trying *different variables and finally found that decreasing the hormone* level from that of our normal program for *T.* 'Densiformis' brought the rooting percentage back up to our previous level.

Sticking the cuttings has been a little slower but not enough to change our rates. It has been trickier to space the cuttings more evenly and it takes a lot more supervision to be sure the depth of sticking is consistent.

In summary, about 10% of this year's crop was harvested with a machine, due primarily to a shortage of cutting wood. We are sticking all cultivars as unstripped 4-in. cuttings. We are still working on perfecting the band saw and hedge trimmer method but this year it will remain R&D. The cuttings will be made individually, screening out the branched cuttings that will require stripping. Hormone treatment will be done by bundle instead of lug and the sticking will be paced to finish in 15 days.

STOCKPLANT ETIOLATION AND BANDING FOR SOFTWOOD CUTTING PROPAGATION: WORKING TOWARDS *COMMERCIAL APPLICATION*

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Abstract. The technique of stockplant etiolation has made it possible to root cuttings of plants which previously could only be propagated by budding or grown from seed. The cost of producing rooted cuttings from etiolated stockplants is approximately $0.05 to 0.10 more per cutting than traditional cutting procedures. The practice of field etiolation can produce a finished plant in the same time as field budding. Greenhouse etiolation substantially decreases the time required to produce a finished plant.

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100% darkness. In fact, a totally enclosed shading structure is detrimental as it would allow too much heat to build up under the shade on sunny days. Some ventilation, such as opening the corners or making cuts in the fabric near the top, is necessary to reduce heat build-up.

After the new growth has reached approximately 2 to 3 in. (5 to 7 cm), a 1-in. (2.5-cm) square band of black velcro whose "wool" and "hooks" have been dipped in an 0.8% indole butyric acid (IBA) talc preparation (Hormodin No. 3) is pressed onto the base of the new growth (the future cutting base), so that the velcro band cannot slide up or down the stem. The new stem is in fact sandwiched between the wool and hooks of the velcro. At this time, the shade cloth is removed gradually over the period of one week so as not to burn the tender etiolated shoots. The band remains on the new shoot for 4 weeks while the top of the shoot is allowed to turn green. After 4 weeks, the shoot is cut right below the band, and the band is removed revealing a still etiolated cutting base which has swollen in response to the IBA treatment. The cutting is then stripped of lower leaves, if necessary, treated again with the same hormone preparation (Hormodin No. 3) and rooted under mist. All deciduous cuttings treated in this way rooted in 4 weeks; some as early as two. Pines, however, took 12 weeks to root. With *Betula* and *Carpinus* species, roots had already begun to form under the velcro bands while shoots were still attached to the stockplant.

Banding on its own without prior etiolation has also proved to be a very effective root promoting treatment. With this treatment, stockplants are allowed to produce 2 to 3 in. shoots and then velcro bands with hormone are applied to the bases of the new shoots in exactly the same manner as described for the etiolation and banding process. The area under the band loses chlorophyll after banding and so is said to be blanched. Those plants which responded more to etiolation or to banding alone are listed in Table 1.

RESULTS AND DISCUSSION

Etiolation trials with several new species proved successful this year. Shoots from *Chionanthus virginicus* seedlings rooted at 80% while shoots from mature *Pyrus calleryana* plants rooted at 87%, when banded alone. *Carpinus betulus* 'Fastigiata' cuttings from mature trees rooted at 100% when etiolated. *Fagus sylvatica* cvs. rooted between 25% and 84% when etiolated.

Further experimentation with the technique suggests that shoots can be banded at the base (as has been described) or in mid-stem with equal success (2). Using *Betula papyrifera*, stockplant age also interacted with the etiolation effect (Table 2).

Shoots from older stockplants were more difficult to root but responded positively to an etiolation pre-treatment, whereas shoots

Table 1. The best rooting percentages obtained from either etiolated or banded cuttings.

Species	Best rooting %	Treatment type
Acer griseum	50	E*
A. saccharum	86	E
A. platanoides	75	E
Betula papyrifera	100	E
Carpinus betulus	96	E
C. betulus 'Fastigiata'	100	E
Castanea mollissima	100	E
Chionanthus virginicus	80	B
Corylus americana 'Rush'	87	E
Fagus sylvatica	64	E
F. sylvatica 'Atropunicea'	25	B
F. sylvatica 'Laciniata'	84	E
F. sylvatica 'Fastigiata'	44	E
Pinus mugo	64	B
P. sylvestris	92	B
P. strobus	83	B
P. thunbergii	92	B
Pyrus calleryana	87	B
Quercus coccinea	46	E
Q. palustris	64	E
Q. robur	70	B
Q. rubra	50	B
Syringa vulgaris 'Belle de Nancy'	65	E
S. vulgaris 'Charles Joly'	63	E
S. vulgaris 'Charles X'	79	E
S. vulgaris 'Michel Buchner'	83	E
S. vulgaris 'Mme. Lemoine'	83	E
S. vulgaris 'Pres. Grevy'	48	E
Taxus × *media*	100	E

E = etiolation plus banding; B = light-grown, banded shoots.

Table 2. The effect of etiolation, banding, and age of stockplant on percent rooting of *Betula papyrifera* cuttings.[1]

Age of stockplant	Etiolated − band	Etiolated + band	Light grown − band	Light grown + band
1-year old seedlings	71%	100%	51%	65%
4-year old trees	63%	68%	10%	15%

[1]Thirty cuttings per treatment

obtained from seedling stockplants also showed a positive if less dramatic response to the pre-treatment.

COMMERCIAL APPLICATION

If this technique is to become commercially viable, it must be compared with current propagation practices. For shade tree production, budding is the method generally used. Trials are underway in cooperation with Schichtel's Nursery, Orchard Park, N.Y.

which seek to compare production schedules, costs, and plant quality of budded and etiolated plants in a commercial nursery.

Initial comparisons of production schedules shows that etiolation may be as fast or faster at producing the same sized plant as budding (Table 3).

Table 3. Comparing production schedules for field budding and greenhouse etiolation

Time of year	Budding	Field etiolation	Greenhouse etiolation
1987			
January			bring in dormant stockplants
February			etiolate stockplants
March			
April	plant out seedling understock	etiolate stockplants	take cuttings
May			cuttings rooted
June		take cuttings	↙ ↘
July	bud understock	cuttings rooted	grow on plant out
August		↙ ↘	in
September		grow on in greenhouse plant out	greenhouse
November			finished plant
1988			
Spring	cut back understock	grow on for another season	
Fall	finished plant	finished plant	

Budded plants are produced by planting out the understock in the spring, budding in mid to late summer, cutting back the understock the next spring, and then growing on the new scion bud for one growing season before sale.

Field etiolated plants can be produced by etiolating stockplants right before bud burst in spring, uncovering and banding the new shoots a few weeks later, leaving the bands on for 4 weeks, taking cuttings by late June or July, and then rooting them in a mist bench for another month. After another season's growth they should be comparable to budded plants in size and quality. Greenhouse etiolation considerably lessens the time it takes to produce a plant of comparable size. Dormant stockplants can be potted up and forced in the greenhouse during January and February thereby producing rooted cuttings by May or June of that same year. The rooted cuttings can then be grown on in the same growing season to produce a finished plant by the end of that year. The cost of producing plants by these three methods is summarized in Table 4.

Table 4. Costs of producing budded liners compared with etiolated field or greenhouse grown cuttings

Budding		Field etiolation		Greenhouse etiolation	
1 year old seedling understock	$0.30	Stockplant maintenance	$0.05	Stockplant maintenance	$0.10
Budding	0.08	Standard cutting production	0.137	Standard cutting production	0.137
Materials	0.01	Etiolation labor	0.03	Etiolation labor	0.03
Maintenance	0.25	Etiolation materials	0.012	Etiolation materials	0.012
Land	0.01	Land and greenhouse fixed costs	0.05	Land and greenhouse fixed costs	0.05
Overhead	0.15	Overhead	0.15	Overhead	0.15
Total cost/plant	$0.80	Total cost/cutting	$0.43	Total cost/cutting	$0.48
Assume 15% loss	$0.92	Assume 15% loss	$0.49	15% loss	$0.55
		Assume 50% loss	$0.65	50% loss	$0.72

Costs of budding were compiled by George Schichtel of Schichtel's Nursery, Orchard Park, New York. To compare etiolation costs the following method was used.

Stockplant maintenance. An assumption of 20 cuttings/stockplant/year was made. Schichtel's Nursery maintenance cost ($0.25/plant) was divided by 20 which gave a cost of ($0.25/20) $0.013. Added on to this was the original cost of the stockplant spread over a 30-year life span assuming 20 cuttings/year. We can assume a $20 cost for the stockplant. Therefore, 30 years × 20 cuttings/year = 600 cuttings which yields a stockplant cost of $0.03/cutting ($20/600). Stockplant costs ($0.03) plus maintenance ($0.013) equals $0.043 per cutting, rounded up to $.05.

Standard cutting production. The Ohio State University publication, "Costs of Establishing and Operating Field Nurseries", (3) was used to develop a per cutting cost of $0.137 based on 11,869 viburnum cuttings produced. Cutting cost included rooting medium, collecting, stripping and sticking, maintenance, harvest, and hormone powder.

Additional etiolation costs. Additional etiolation costs were computed as follows. At $6.00/hr one person can band 240 shoots which equals $0.025/shoot ($6.00/240). With the addition of labor for shading the stockplants initially this figure can be rounded up to $0.03. Materials for etiolation (shade cloth, velcro, hormone powder) added another $0.012 per cutting.

Fixed costs. Fixed costs were calculated from the same bulletin (3) and overhead was supplied by Schichtel's Nursery.

The only difference in these figures with greenhouse etiolation

procedures comes in the 10 to 12 weeks when stockplants are brought into the greenhouse for forcing in winter. Based on a $1.00/ft^2/year greenhouse production cost, 12 weeks of heating a 2 ft^2 area for the stockplant would equal $0.025/cutting ($2.00 × .25 year = $.50/20 cuttings). Additional media based on 6.50/yd^3 = $0.005. Stockplant containers (5-gal containers/stockplant) for 5 years at $0.01 per cutting, and labor for potting up at $6.00/hr, potting up 30 plants/hour = $0.01. Greenhouse costs ($0.025) plus media ($0.005) plus cost of container ($0.01) plus labor ($0.01) equals = $0.05 additional cost per rooted cutting of bringing stockplants into the greenhouse in winter.

Initial plant quality appears very good; however, further work comparing rooted cuttings with field-budded liners will be undertaken next year.

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PROPAGATION OF AZALEAS FOR CONTAINER AND FIELD PRODUCTION

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Propagation of azaleas at Van Hof's begins about the last week of August, when cuttings are taken either from bedded plants, containers, or lined-out material. Having these choices of locations assures that good healthy cuttings will be taken.

CUTTING PREPARATION AND STICKING

After gathering the cuttings, they are brought back to the nursery where the lower leaves are stripped. A fresh 45° cut is made, and then #2 Hormodin powder is added.

Although the length of the cutting is not critical, we believe that a 5½-in. cutting is ideal, for the following reasons:

1) For ease of handling and ease when sticking into the peat and perlite medium.
2) Transplanting the rooted cutting into the growing bench.
3) Branching is low to the soil level when the cuttings begin to grow.

The cuttings are then transferred to the propagation house where they are stuck into a bench of peat:perlite (1:1, v/v). We have found that a depth of 6 in. of peat and perlite provides good drainage. When spacing the azaleas cuttings, we use a spacing stick for this process to get a 1¼ × 1¼ in. spacing.

MISTING

Mist is provided by using the Phytotronics control system. This system allows for settings from 2 to 64 min. between misting cycles and settings from 2 to 16 sec. of "on" time. A 24 hr clock regulates the time the misting begins and ends. The misting sequence begins at 9 a.m. and ends at 5 p.m. The propagation house is shaded with a 51% shade cloth, so the mist control is adjusted daily. Ventilation fans are set for 80°F and, when needed, heat is set at 70°F.

Within 5 to 6 weeks rooting has taken place and the mist is gradually eased off until it is completely shut off after 7 to 10 days. The shade cloth is removed from the house at this time.

TRANSPLANTING

The rooted cuttings are transplanted around the end of November to a bench containing peat:perlite (1:1, v/v). Spacing is now 2½ ×

2½ in. These plants will be kept at 45°F until February when the greenhouse temperature will be raised to 70°F. At this time we also begin to fertilize. Later, in May, the house will be shaded with a 51% shade cloth.

FERTILIZATION

Fertilization with Peter's 20-20-20 is done using a Gewa injector, 6 gal model. We use the number 3 setting on the Gewa injector which provides a ratio of 1 to 100 and a concentration of 16 oz of fertilizer to one gal. Fertilization is done every other watering.

TRIMMING

Trimming begins when we pinch the flower buds in February. This promotes rapid growth of new shoots and also keeps flowers from decaying in the bench. When the new growth has matured half of the new growth is cut off with shears. Hand shearing ensures that each plant is trimmed correctly. The next two or three times the azaleas are trimmed will be with electric hedge shears. After each trimming we use a Shop-Vac to pick up the cut material. This helps in preventing disease, especially as the plants grow larger. The last trimming is done before the plants are removed from the propagation house.

TRANSPLANTING INTO CONTAINERS

Transplanting the azaleas into containers is done in May or June. Plants are pulled from the propagation house and placed in flats. Then they are brought out to the potting machine and put into a 1.5-gal container. We use a mix consisting of 16 yards washed sand, 50 bales of 6 ft^3 peat moss, 360 lb high magnesium lime, and 43 lb triple superphosphate.

After planting, a top dressing of twelve grams 18-6-12 Osmocote, 9 month formulation, is used. Containers are placed pot to pot for the first year. Then they are spaced and trimmed for the second year.

Winter care of azaleas begins in early November. Plants are irrigated, then poly is used to cover the shelters. Irrigation is continued through the winter as needed.

BED PLANTING

Rooted cuttings are bedded out ideally in April to May in beds 62 in. wide. They are spaced at approximately 6 in. on center.

LAND PREPARATION AND PLANTING

Land is prepared by using 800 lb/A of 19-19-19, (nitrate form of nitrogen.). Beds are staked out roughly 300 ft long. Fifteen bales of

peat moss are broken down inside the beds, then rototilled to produce a 12-in. depth of soft soil.

Planting is done by hand using trowels. Aged sawdust is used as mulch, and 50% shading is provided by wood lath shades. We use a herbicide (Devrinol 50% wetable powder) at 8 lb/A. In the fall of the same year, an additional feeding of 800 lb/A of 15-15-15 ammoniated fertilizer is used for a quick intake and retention of nitrogen to become available when plant activity begins the following spring.

In the spring, about the third week of March, shades are removed and another herbicide treatment, Surflan, is used. When bud elongation becomes evident, urea is applied at the rate of 150 to 170 lb/A and irrigated into the soil. Factors such as rainfall, foliage color, and temperature are considered before further application of urea. Four to 5 treatments of urea are possible. Azaleas will stay in the beds for 2 years.

FIELD PLANTING

Land preparation, and herbicide and fertilizer applications are the same as in bed planting. The plants are lined out using a Two-Row planter. Planting is done during June and July. The azaleas will stay in the field for 3 years.

FALL DIGGING

When possible, fall digging begins at the end of October. The plants are balled and burlapped, loaded on trucks, watered, then stored in a sheltered area.

GENERAL INFORMATION

The azaleas grown at Van Hof Nurseries, Inc. are: *Rhododendron mucronatum* [syn. *R. ledifolium* var. *album*], *R.* ×*stewartstonianum*, and the cultivars *R.* 'Carmen', 'Cornell Pink', 'Delaware Valley White', 'Girard's Hotshot', 'Hino Crimson', 'Kaempo', 'Mother's Day', and 'Rosebud'. *Rhododendron yedoense* var. *poukhanense* is grown from seed. The seed is collected in the fall from our field plants. The seed is sown in flats in November and then transplanted into flats in February. There are 130 plants per flat. These plants will be bedded out in the spring. We grow 30,000 azaleas a year, with 12,000 for containers and 18,000 bedded out.

Thursday Afternoon, December 11, 1986

The Thursday afternoon session convened at 1:30 p.m. Mark Bridgen serving as moderator.

LINER BED HERBICIDE UPDATE

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INTRODUCTION

The value of the liner crop based on the area occupied (amount of land) is extremely high and it is not cost effective for the herbicide industry to label herbicides for use in liner beds. This means that the nursery industry will need to do most of its own research to determine what herbicides will be effective and safe for use in liner beds.

The use of herbicides in liner beds should be done only after careful evaluation of the existing weed problems, the liner species being grown, and the bed medium. To do otherwise is courting disaster.

The purpose of this paper is to describe how a nursery should develop a weed control system for its liner beds including an in-house research program.

DEVELOPING THE WEED CONTROL SYSTEM FOR LINER BEDS

The first rule in any pest management program is to identify the problem. This is especially true with weed control problems. You must know what weeds are causing the most problems in the liner beds before you can select an herbicide or develop a weed control system.

After determining the major weed problem the next step is to start clean. The liner beds need to be free of perennial weeds. To accomplish this may require the use of soil fumigates or steam pasteurization. Dr. Elton Smith has published the techniques for steam pasteurization and chemical fumigation of liner beds in his publication, *Chemical Weed Control in Commercial Nursery* and *Landscape Plantings* from The Ohio State University. Besides the soil fumigants listed, such as Picfume, Larvacide 100, MC-2, Pano-Brome C1, Vapam, VPM, and Vorlex, one should include Basamid, or Mylone. Basamid, or Mylone, is relatively new and is worthy of evaluation as a soil fumigation treatment. There has been some con-

cern with the loss of mycorrhizal fungi when soil fumigation has been used and I believe that this is a legitimate concern. To determine whether there are adverse or positive effects of the treatments, always have *several* untreated areas. Compare carefully the liner growth (root and shoot) from the treated area and from the untreated area.

Some guidelines in setting up the untreated checks might be appropriate. First scatter the checks throughout the beds. Do not leave ends of beds untreated as the checks since other factors such as moisture might influence the growth. Always make certain the same plant species, cultivar, age, etc. are being compared. Be prepared to hand weed the check area.

The cost of soil fumigation is high (maybe as much as $1000/acre) but compared to the cost of hand weeding the liner beds it would be cost effective to use fumigation.

Once the site is weed-free the next step is to apply the appropriate preemergence herbicides to maintain weed control in the crop. Some preemergence herbicides such as Treflan can be used pre-plant but most will be used post-plant. Before selecting the herbicide you must match the weed problem with the herbicide and then determine if that herbicide can be used safely on the plant. Remember most herbicides will not be labelled for use in liner beds and some herbicides cannot be used on liner beds. Rout is one such herbicide. Also, conifer seed beds are not the same as liner beds (rooted cuttings). Since most herbicides are not labelled for use on liner beds you will have to do some research on your own.

First, always make trial areas. Do not treat whole beds until you have experimented with the herbicide. Evaluate the growth response of several cultivars since there often are cultivar differences in response to herbicides. Secondly, set up checks (no treatment areas) as described for soil fumigation. Rate the growth of the plants in both treated and untreated areas.

Dr. Elton Smith recognized the need for the use of herbicides in liner beds and in his publication lists the herbicides that have been evaluated by him as being useful for weed control in liner beds. The herbicides listed are:

Dacthal	—Primarily annual grass control and fairly short-lived.
Dual	—Primarily annual grass control. Combined with Princep it can be used on some evergreens.
Enide	—Annual grasses and more broad-leaved annuals than Dacthal; longer lasting.
CIPC	—Chickweed control.
Kerb	—Perennial grasses and must be applied late in fall before the soil freezes.
Princep	—Used at reduced rates and in combination with grass control herbicides.

Treflan —Preplant annual grasses; short-lived.
Devrinol —Annual grasses and broad-leaved weed control.

Other herbicides can be tried but the key word is *tried*. Do not treat whole beds before gaining experience with a particular herbicide.

The postemergence grass herbicides such as Poast and Fusilade can be used to remove established grasses from liner beds. Fusilade provides better control of perennial grass than Poast. Wayne Lovelace reported last year on a technique using Poast to remove a grass cover-crop from seed beds. This is an excellent technique. Read the labels carefully on these products. The Fusilade label has been expanded but some plants require a directed spray and some will exhibit as much as 50% injury.

CONCLUSIONS

The use of herbicides in liner beds should be done only after careful evaluation of the weed problem, plant being grown, and soil types in the liner bed. Develop a total weed control system for the liner beds. Use the following techniques:

1. Determine the major weed problem.
2. Start clean—use soil pasteurization or fumigation if necessary.
3. Before or after planting use a preemergence herbicide.
4. Select herbicides that will control the weeds and be safe on the crop.
5. Always leave untreated areas and check growth of liners against the growth in herbicide-treated areas.
6. Never use an herbicide in the whole liner beds until it has been tried.
7. Remember to check cultivars as well as species for growth response.

PRAIRIE PLANTS IN THE GARDEN

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Illinois is known as the prairie state, but little of the original prairie remains. A resurgence of interest in the planting of display gardens as well as actual prairie reconstruction is happening at the present time. Hopefully, no more virgin prairie will be destroyed in the future. The public has been informed and all we need to do is keep the interest going. The use of prairie plants in a garden is just a small way that we in the field of horticulture can help with conservation.

The Chicago Botanic Garden has begun planting a display garden with prairie grasses and forbes. Our display of these plants is not only ornamental but is used as a learning tool for the interested public who chooses to see plants displayed in landscape settings. Classes are held for plant identification as well as prairie construction. In addition to these, a tram stop is being planned for next year to be able to make people more aware of the beauty and ornamental qualities of these plants. We collect seeds in the wild, process them according to the proper method or methods, and plant them in the prairie in the early spring. Large numbers of plants are required. Propagation techniques for these prairie plants vary with genus and species. Most of the perennials occur in nature where extremes in temperature during both winter and summer are commonplace, and the plants have adapted to their locations. This can pose problems for the plant propagator. Division, one of the oldest and most common means of propagation for perennials is often unworkable for some prairie plants. Very deep root systems, often like a tap root, form in some plants rendering division impractical. Exploding seed heads, ephemeral qualities and normally poor germination are all difficulties to be taken into consideration when choosing a proper method of propagation.

Plant selection is a highly subjective subject. Many qualities enter into the selection and everyone has different characteristics to meet the criteria. The professional plant propagator is faced with all the aesthetic choices as well as the important one of ease of propagation. Fortunately for professionals, the prairie perennial plants are easy to grow by most conventional methods. The following (highly subjective) list is made up of easy to propagate, ornamental, non-invasive, readily obtainable and, to the author, PERFECT PLANTS!

Amorpha canescens, lead plant. A shrub to 3 ft with dense violet flowers on new wood from mid-June to mid-July. Flowers the 4th or 5th year from seed. Best propa-

gated by seed collected from August to October. Seed treatment: soak seeds in 180°F water, allow to cool then stratify for 60 days at 41°F.

Anemone patens, pasque flower. A perennial with flowers pale lavender. Best propagated by seed collected from May to early June. Seed treatment: sow fresh or stratify 21 days at 41°F.

Asclepias tuberosa, butterfly weed. A perennial to 2 ft with brilliant red, yellow, or white flowers mid-June to mid-August. Flowers the second year from seed. Best propagated by seed collected from September to October. Seed treatment: stratify 30 days at 41°F.

Aster sericeus, silky aster. Perennial to 2 ft with rosy-blue flowers in September and October. Best propagated from divisions in either spring or fall.

Baptisia leucophaea, cream false indigo. Perennial to 2 ft with creamy yellow flowers from late May to June. Flowers the 5th year from seed. Best propagated from seed collected in August and September. Seed treatment: stratify 130 days at 41°F.

Dodecatheon meadia, shooting star. Ephemeral perennial to 2 ft, with white to pale pink flowers in May and early June. Flowers the 4th or 5th year from seed. Best propagated by division in July.

Euphorbia corollata, flowering spurge. A perennial to 3 ft with tiny white flower clusters from June to September. Best propagated from seed collected in early September. Seed treatment: stratify 60 days at 41°F.

Filipendula rubra, queen of the prairie. A perennial to 3 ft with deep pink flowers in July and August the second year from seed. Best propagated by division.

Oenothera pilosella, prairie sundrops. Perennial from 1 to 3 ft with lemon yellow flowers from July to September. Best propagated by softwood cuttings in spring.

Petalostemum purpureum, purple prairie clover. A perennial to 3 ft with purple flowers from July to mid-August the second year from seed. Best propagated from seed collected during August and September. Seed treatment: stratify 30 days at 41°F.

Physostegia virginiana, false dragonhead. A perennial with pink to white flowers in terminal spikes during August and September. Best propagated by division in spring.

MYCORRHIZAL INOCULATION DURING PLANT PROPAGATION

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Mycorrhizae are the symbiotic associations of certain soil fungi and plant roots. Hyphae of mycorrhizal fungi are in close association with the cells in the outer region of the root and extend outward into the soil, effectively increasing the surface area of the root system. Mycorrhizae have been documented for nearly all plants in their natural habitats.

Since this is a symbiotic relationship, both the plant and the fungi benefit. The plant benefits primarily from increased nutrient and water uptake, while the fungi benefits from the use of the plant as a source of carbohydrates and plant exudates.

Research with ornamental plants has focused on both ectomycorrhizae and endomycorrhizae. Ectomycorrhizae form a visible hyphal sheath around root tips and are responsible for the characteristic branching of ectomycorrhizal roots. Within the root, the hyphae surround, but do not penetrate individual cells. Unlike ectomycorrhizae, endomycorrhizae are not visible without magnification. In endomycorrhizal relationships, the hyphae penetrating the roots actually enter individual cells. Endomycorrhizae are characterized by arbuscles and vesicles structures. Arbuscles are concentrations of fine hyphae which form and dissolve, and may be a means of exchange between the two symbionts. Vesicles are lipid droplets which when thin-walled serve a function of storage, and when thick-walled can act as resting spores.

There is increasing evidence that mycorrhizal inoculation may effectively increase plant growth under cultural regimes typical of commercial production (2, 4, 7, 8, 9). This paper will focus on the importance of mycorrhizal inoculation during plant propagation.

CUTTING PROPAGATION

When endomycorrhizal inoculum is included in a propagation medium, substantial gains in the establishment of roots can result (7). Cuttings of *Viburnum dentatum* were rooted under mist in a medium of perlite:vermiculite (1:1, v/v), or in the same medium amended with inoculum at a ratio of 7 medium: 1 inoculum (5 spore/cm^3).

Inoculum consisted of isolated spores of *Glomus fasciculatum*. Cuttings were 20 cm in length, had 6 leaves and were treated with 0.1% IBA. Number and weights of roots were measured after 4, 5, 6, 7, and 8 weeks of rooting.

Inoculum significantly increased the number of root initials

penetrating the stems of cuttings after 5 weeks of rooting, with smaller increases on subsequent weeks (Table 1). This effect on root initiation occurred only after roots had begun to form and could be infected. This increase in number of roots is probably mediated through an effect of the fungus on plant metabolism, rather than a fungal exudate into the rooting medium.

Table 1. Effect of the mycorrhizal fungus, *Glomus fasciculatum*, on number of root initials formed by cuttings of *Viburnum dentatum*.

	Number of root initials	
Week	Inoculated	Control
4	5.25 c	2.25 c
5	33.75 ab	8.25 c
6	33.50 ab	25.00 b
7	49.75 a	34.25 ab
8	42.75 ab	27.50 ab

Numbers followed by the same letter are not significantly different at the 5% level.

Glomus fasciculatum also increased the fresh weight of roots of these cuttings after 7 weeks of rooting (Table 2). Soon after roots could be infected by the mycorrhizae, growth enhancements began.

There is no evidence from this work that fungal exudates are present in large enough concentrations to influence rooting prior to fungal infection. This supports the theory that roots first must be present before infection can occur and there can be any beneficial effect of the inoculum (Fig. 1).

Table 2. Effect of the mycorrhizal fungus, *Glomus fasciculatum*, on fresh weight of roots formed by cuttings of *Viburnum dentatum*.

	Root fresh weight (g)	
Week	Inoculated	Control
4	0.0000 d	0.0000 d
5	0.0083 d	0.0033 d
6	0.0000 d	0.0000 d
7	0.5091 b	0.2793 c
8	0.7736 a	0.2605 c

Numbers followed by the same letter are not significantly different at the 5% level.

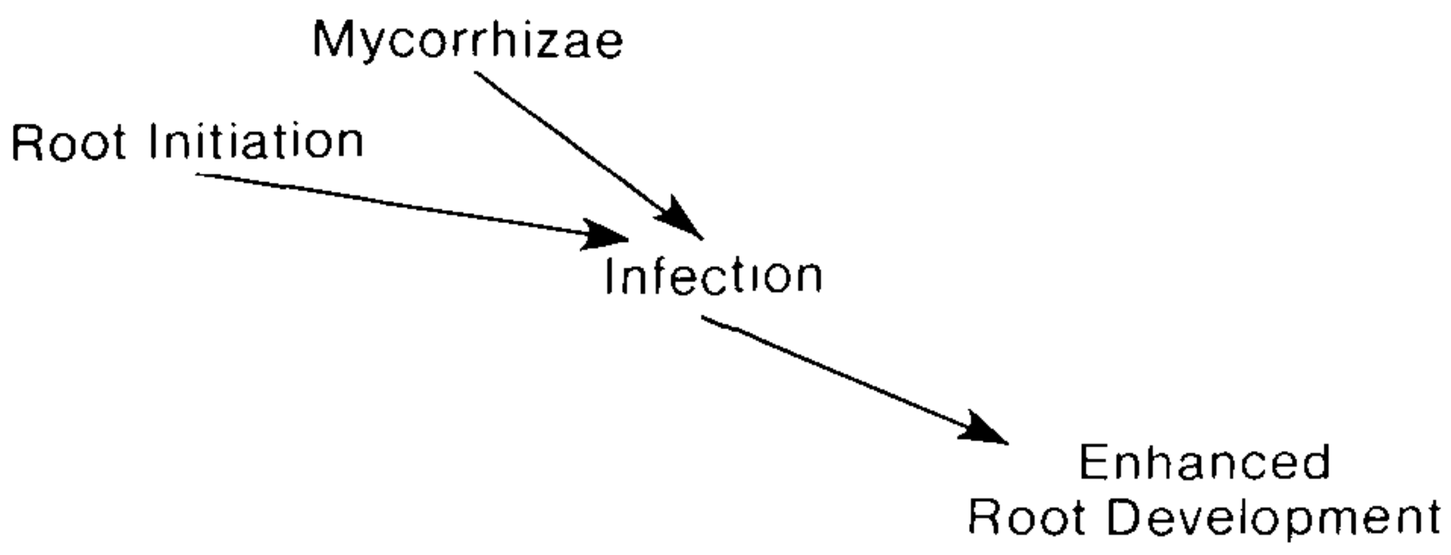

Figure 1. Sequence of events which would require infection occur prior to a beneficial effect of mycorrhizae on root growth.

Work by Linderman and Call (3) with ectomycorrhizae indicated an effect of inoculum on rooting before, or in the absence of fungal infection. This enhancement of rooting may be due to the exudation of auxin by the fungi (Fig. 2). This theory is supported by the fact that the appearance of an ectomycorrhizal root system can be induced by auxin treatment (6). Although these theories about the effect of mycorrhizae on rooting have not been tested, they are not mutually exclusive because ectomycorrhizae may have higher auxin exudates than endomycorrhizae.

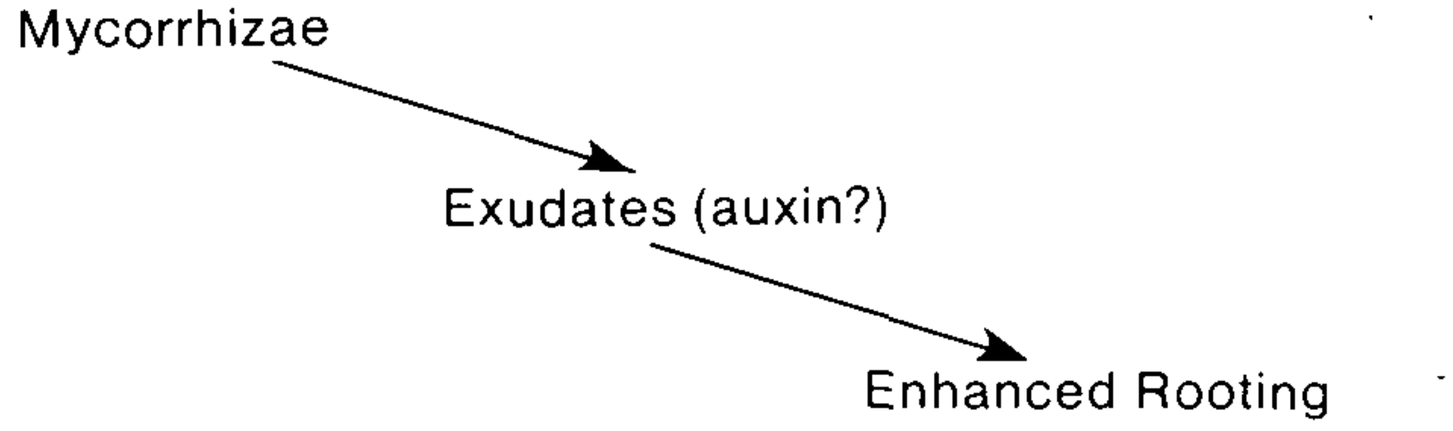

Figure 2. Sequence of events in which mycorrhizae could have a beneficial effect on rooting prior to, or in the absence of, rooting.

SEEDLING PROPAGATION

Seedlings can also benefit from the incorporation of mycorrhizal inoculum into the propagating medium. The objective of this experiment was to examine the extended effects of mycorrhizal inoculation during propagation on growth of seedlings following transplanting. Seedlings of *Cornus sericea* were germinated in media inoculated with *Glomus fasciculatum* or *Glomus macrocarpum*. Seeds were sown 0.25 cm deep in medium of perlite:vermiculite (1:1, v/v) or the same medium inoculated with isolated spore of *Glomus fasciculatum* or *Glomus macrocarpum* at a rate of 4 spores/cm^3. After 16 weeks the seedlings were transplanted into 1-quart (116 cm^3) pots and grown for 16 additional weeks. Data included plant height and dry weight of shoots.

Seedlings inoculated with mycorrhizal fungi attained a greater height and dry weight of shoots than non-inoculated plants (Figs. 3 and 4). Plants inoculated with *Glomus fasciculatum* had the greater height and dry weight of shoots than those inoculated with *Glomus macrocarpum*. Mycorrhizal infection of seedlings during propagation promoted seedling growth and had beneficial effects which extended beyond the propagation phase of production.

MICROPROPAGATION

It is possible to introduce fungal spores directly into tissue culture (1); however, this can present some potentially very serious problems with contamination. It is currently more feasible to inoculate stage IV plants while root systems are expanding. These plants

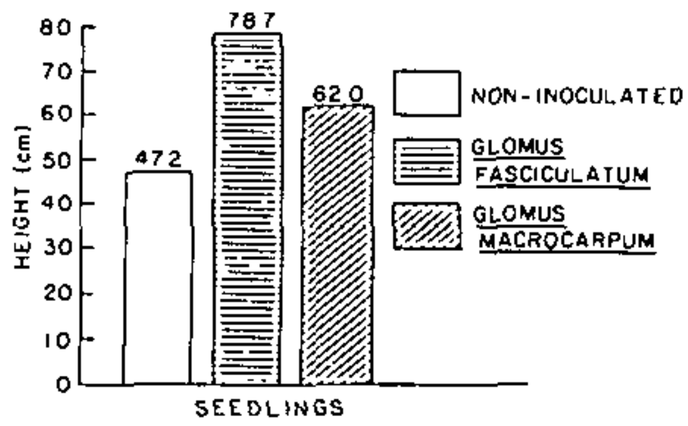

Figure 3. Effect of *Glomus fasciculatum* and *Glomus macrocarpum* on height of *Cornus sericea* seedlings.

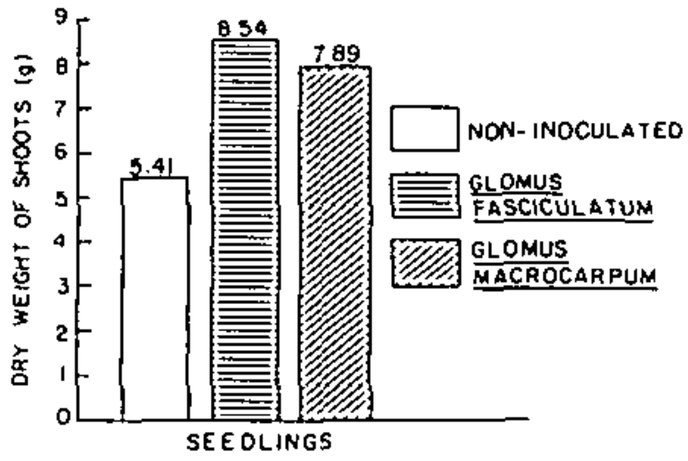

Figure 4. Effect of *Glomus fasciculatum* and *Glomus macrocarpum* on shoot dry weight of *Cornus sericea* seedlings.

could be inoculated in much the same manner as cuttings and seedlings.

CRITICAL STAGE

An important point to consider is that propagation is the critical stage of production for mycorrhizal inoculation. Propagation is the most logical stage of production for mycorrhizal inoculation. Inoculation during propagation enables the earliest possible infection and resulting benefits. It also facilitates efficient inoculation because a large number of plants can be inoculated in a small area. Cuttings, seedlings and tissue culture plants also can all be inoculated in propagation and handled the same way, using the propagation media as a carrier for inoculum. For these reasons, I am confident that if mycorrhizal inoculation is to become routine for production of any plants, propagators will be at the heart of this activity.

INOCULATION PROCEDURE

Figure 5 illustrates a possible scheme for inoculation with endomycorrhizae. Endomycorrhizae are considered obligate symbionts, and therefore must be grown with plants if they are to be grown for any period of time. In this scheme, inoculum sources are built up by "pot cultures" which enable the number of spores and hyphae to increase (5). The soil containing the roots, hyphae and

spores can be used as inoculum, or spores can be isolated and used as inoculum. The use of isolated spores reduces the risk of a contaminant being present in the inoculum.

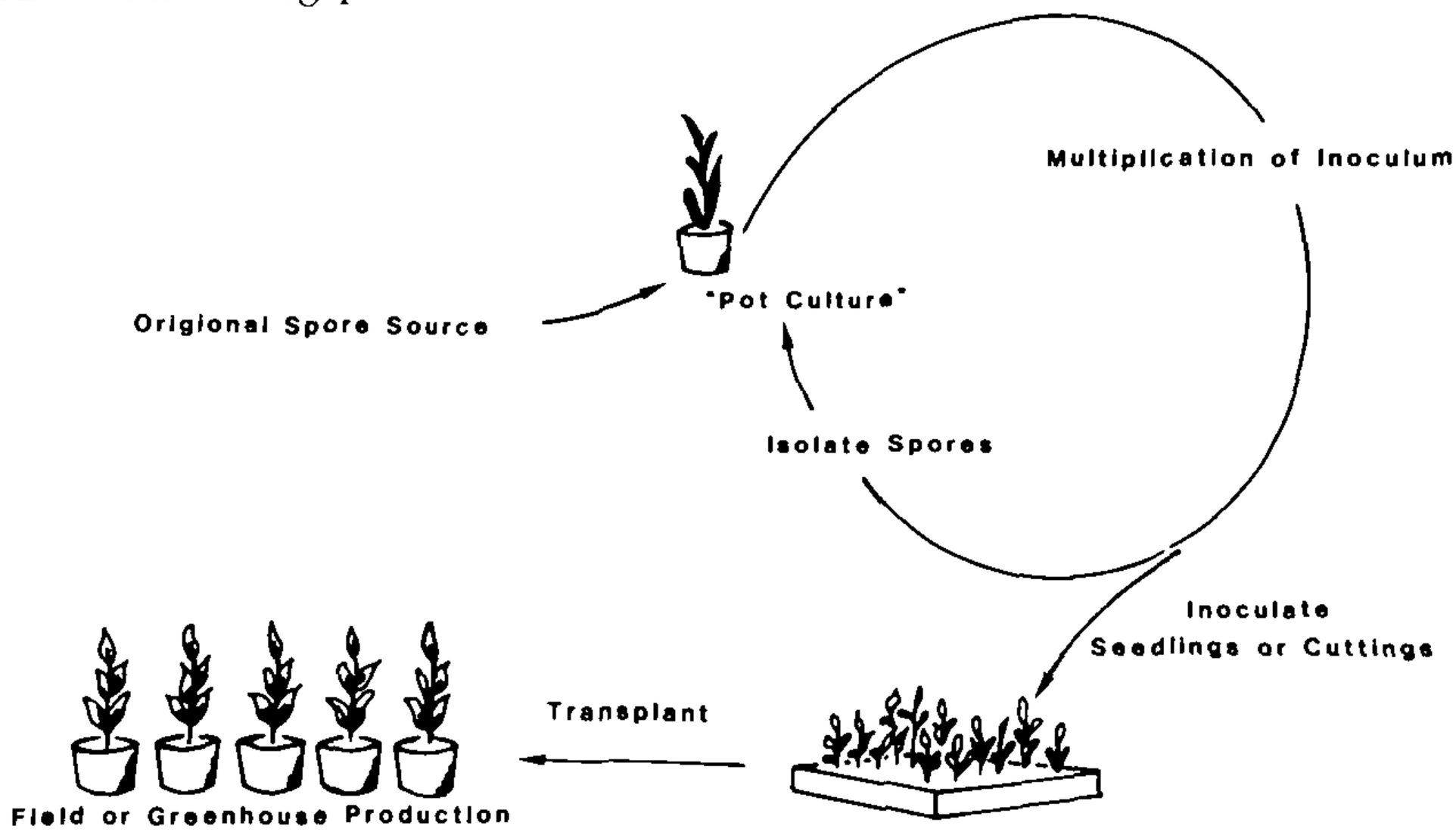

Figure 5. Diagram depicting a scheme for endomycorrhizal inoculum production and inoculation during production.

Inoculation is most efficient when the plant density is high, as in propagation. A determined volume of inoculum should be mixed into the propagation medium to facilitate infection as the roots develop. As propagation is achieved, the plants can become mycorrhizal and will benefit from inoculation during propagation, during field production, and when growing in the landscape.

A small amount of inoculum must be retained to perpetuate the "pot cultures" which serve as the inoculum source for future crops. Prior to initiating new pot cultures the spores must be isolated to reduce the risk of perpetuating any contaminants which may have become established.

CONSIDERATIONS FOR USE

Nurseries that experiment with mycorrhizal inoculation in a production system should be sure to:

1) Use the fungal species which will maximize the growth of the plant you are growing.
2) Use selective pesticides to prevent an unwanted effect on the mycorrhizal fungi.
3) Determine the cost of maintaining an inoculum source and the cost of the added step of inoculating.
4) Determine the value of the growth increases obtained

through inoculation. This value must be greater than the cost of inoculation for the inoculation to be practical.

Will mycorrhizal inoculation become a routine practice in nursery production? The answer to this question will be best answered by nurserymen. Researchers and nurserymen will need to cooperate to conduct research trials on actual nursery sites using commercially important plant species to identify and solve any problems which might occur due to the incorporation of mycorrhizal inoculation into production. Only actual attempts to use this new technology will truly answer the question of the potential for mycorrhizal inoculation in nursery production.

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TAXUS PRODUCTION AT THE RHODE ISLAND NURSERIES

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Rhode Island Nurseries, Inc. has grown to become a 500-acre, field growing, wholesale nursery since its founding in 1896. Much has changed in this time but it remains in the control of the Vanicek family and still considers the genus *Taxus* to be their specialty. With such introductions as *T.* ×*media* 'Densiformis' and *T.* ×*media* 'Nigra' they stand ready to embark on the next 90 years with the same drive and dedication to the nursery industry.

From the time the Taxus cuttings are stuck until they are sold the nursery will lose roughly 20% of them. Much of this loss comes from grading out the weaker or less desirable plants, as opposed to cultural (disease, insects) and mechanical damage. Eleven cultivars of *Taxus* are stuck each season. The average yearly total for all 11 cultivars is 150,000 cuttings. Within 8 to 9 years, depending on the cultivar, 115,000 plants will be sold.

The taking of cuttings begins in mid-November and is usually finished by the 2nd week in December. The source for these cuttings are the nursery's 6 to 11 year old plants. These plants have been planted on 3 ft centers for 2 yr and will remain for 2 more yr before being sold. Estimates of the number of cuttings a plant will yield are made in summer. A specific number of rows are set aside to insure that an adequate supply of cuttings will be available. All other plants are trimmed at this time.

In mid-November the crew enters the field and works one cultivar at a time. The workers are careful in their selection, so as not to deform or impede the growth of the plants. Cuttings are taken with small hand shears and placed into wooden boxes. The boxed cuttings are then transported to the propagation facility. They are watered and then all, except those needed to keep the crew working, are placed in a walk-in cooler that is set at 37°F.

The initial cutting is 8 to 10 in. long. Each man draws one of these and strips off the lower 3 to 4 in. of needles and shoots. After doing this to a dozen or so, bunching them in one hand, a guide stick is used to gauge uniform height. All stems are given a fresh cut and the tops are pruned to gain uniformity. Finished cuttings are 7 in. long and are set to one side and the process continues.

The cuttings sit (about 30 min) until enough are made for sticking. Two people working together, generally do all the treatments and sticking. For *Taxus*, the treatment is a quick-dip into a solution that is 50% Chlormone and 50% water. [Note: *Taxus baccata* 'Repandens' is treated in a solution that is 75% Chlormone and 25% water.] The cuttings are then promptly stuck into the

benches filled with 8 in. washed concrete sand. [Note: The sand is carried in during the previous weeks and has been pounded down to provide support.] A heavy dibble stick is used to assist in the sticking, and to re-pack the sand around the cuttings. Rows are 1 in. apart with spacing within the row of approximately ½ in. Spacing is modified somewhat depending on the peculiarities of each bench (i.e. a hotter bench needs greater spacing).

Bottom heat, from hot water circulating in pipes beneath each bench, is provided immediately. The desired root zone temperature is 65°F. Once callus has formed, the root zone temperature is increased to 70°F for the duration. The tops of the cuttings are subject to heat only from residual bottom heat or solar build up.

All cuttings are watered as needed, generally once or twice a week. Measures are taken continually to ensure proper humidity. Through careful watering and, on occasion, use of electric fans, to provide air flow, humidity is not allowed to develop to a critical state. Excess humidity can lead to several problems—an outbreak of *Rhizoctonia* being one of the most damaging.

The *Taxus* cuttings remain in the rooting bench until late May or early June. They are then transplanted from the rooting bench inside to shaded growing beds outside.

This process starts with the assembly of the rooted cuttings. The rooted cuttings are pulled out of the sand and graded (roots vs. no roots). All cuttings have their tops and roots pruned. All roots are also rinsed in a solution of Rapid-Gro (rate = 1 tablespoon/gal). After the rooted cuttings are pulled, pruned and dipped, they are assembled in wooden boxes (approximately 10 × 10 × 18 in.). These boxes either go directly to the planting area or into the walk-in cooler.

Simultaneously the land is being prepared for planting. The preparation begins with the application of a layer of cow manure, roughly 2 in. thick, over the entire field. The manure is promptly disc-harrowed, and the field is then plowed. Plowing is done to a depth of 24 in. After the field is replowed and reharrowed, the field is then rototilled twice and is only now qualified to be planted.

All *Taxus* beds are planted with an Edgal 6 row bed planter. Beds are 4 ft wide and their length varies depending upon field size. The rows within each bed are 8 in. apart and plants are spaced 6 in. apart within each row. (Beds are approximately 2 ft apart.)

When it is time to plant, the boxed rooted cuttings are placed on the machine in front of each worker, so that the bed planter can be fed. As the tractor pulls the planter along, two workers follow making certain all are placed at a proper depth and that there are no misses.

The beds are then tramped. Each row is packed down by foot to bring the soil in firmly around the root zone. Afterwards, the beds are scratched to loosen up the soil surface and level off the entire bed surface.

Mulch is then applied. Mulching assists greatly in weed control, as well as in moisture retention for the young plants. Since shredded sugar cane is no longer available, several substitutes have been tested. To date, only two come close to matching the excellent qualities of sugar cane: rye straw, which is bought in, and sudan grass, which is harvested on site.

Both, however, have their drawbacks. The rye straw does not mat quickly and is easily blown away until it does so. Also, regardless of any claims to the contrary, there is always volunteer rye. The Sudan grass fares somewhat better. A major drawback here could be that it only lasts about 1 yr before it breaks down (we would like it to stand up for 2 yr). Also, the necessary room to grow Sudan grass and machinery to process it must be available.

After a mulch is applied, stakes are driven along either side of the beds. Shades are placed on these about 18 in. above the beds. The shades are nothing more than a 4 × 6 ft frame with lath. They provide 56% shade. The shades are removed during the second summer to facilitate further hardening off.

These *Taxus* plants will remain here for 2 yr. Maintenance during this period will include periodic weeding, pruning, and scheduled applications of pesticide.

From this 2-yr bed the *Taxus* are lined out for an additional 2 or 3 yr. [*T. cuspidata* and the *T.* × *media* cultivars 'Densiformis', 'Halloriana', and 'Hicksii' are lined out for 2 yr; *T. cuspidata* cultivars 'Brevifolia', 'Brownii', 'Hatfieldii', 'Tauntonii' and *T.* × *media* cultivars, 'Nigra', and 'Repandens' are lined out for 3 yr]. Land preparation is the same as that for bed preparation. Harvesting is also similar.

For lining out, the beds are undercut with a custom-made bed digger. The plants are pulled out and the roots pruned with a hand knife (the tops had been trimmed the previous summer). They are graded, assembled into boxes, and sent to cold storage or the planting area. All planting, at this stage, is still mechanical. A two-row planter is now utilized.

The planting machine is tractor-pulled with 4 workers feeding 2 rows. The *Taxus* are lined out in rows 3 ft wide with spacing of 12 in. within the row. As in the bedding procedure, two persons follow the machine, making certain there are no misses and the plants are at the proper depth. When planting is completed, all the lines are tramped. The entire field is then cultivated, either by a tractor-pulled, three-row cultivator or by a single-row, mule-pulled cultivator.

Just this year, 1986, we began experimenting with herbicides. [Note: only liners have and ever will be subject to herbicides.] Aside from this, maintenance includes yearly pruning, cultivating and weeding, as necessary, and scheduled pesticide applications.

When the 2 or 3 yr term has ended, the *Taxus* are transplanted

for the final time. This move will occur in the fall.

The lined out *Taxus* have their tops pruned in mid-to late summer in preparation for this move. As the land to be planted is being prepared, the liners are harvested. A two-row root pruner is used to help lift the plants to the surface. The liners are then pulled out of the ground, and all soil is shaken off of the roots. They are graded and then root pruned with a hand knife. After assembling into boxes, which measure 12 × 12 × 48 in., the liners are sent to be watered and stored in a shed, out of the wind and sun.

Once the field to be planted is properly marked, the boxed liners are re-watered and sent to the field. Here they are distributed throughout the field and all planting is done by hand. The plants are "check-planted" on 3 ft centers. (Rows are 3-ft wide with 3 ft spacing in each row. This planting system facilitates cross cultivation, which is the primary form of weed control.)

When the entire field is planted, the plants are tramped. Oats, as a cover crop, are applied and cultivated into the soil. In 2 yr, these plants will be the source of *Taxus* cuttings and the whole process will repeat.

In total, the *Taxus* remain at this final stage for 4 yr, after which in the spring they are harvested and sold. During those 4 yr, they require constant cultivation. Each field will be cultivated for weed control once every 3 to 4 weeks. Generally, a crew with hoes will follow to get any weeds, which may have been missed. Pruning is critical at this stage. Efforts are made to gain maximum uniformity without hindering maximum growth. Scheduled pesticide application becomes more important as well. Beginning June 15, Orthene is applied to all *Taxus* as a defense against black vine weevil. July 15 a program against scale is started using malathion.

A fertilization-assist program has recently been in effect for *Taxus*. In late May—early June all final stage *Taxus* are side dressed during the last growing season before harvest. This provides a more colorful, vigorous plant to be delivered to the customer.

From start to finish, every *Taxus* plant produced is under complete control. By having a ready supply of cutting stock, Rhode Island Nurseries can form, direct, and guide the plant for its entire life. Through pruning and trimming at the earliest stages of development, quality and uniformity are assured. The root systems, alone, are pruned four times within 8 to 9 yr. The tops receive attention at least once every year for the same period.

But it all begins with a good selection of cuttings and devoted attention during their development. This should be considered the most critical stage, where traits are developed and carried through for the duration of that plant's life. If a plant starts weak or diseased, it will never keep pace and, as such, becomes a liability.

EFFECT OF A HYDROPHILIC GEL ON GERMINATION OF WOODY LEGUME SEEDS

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Abstract. Seeds of black locust (*Robinia pseudoacacia*), common honeylocust (*Gleditsia triacanthos*), and Kentucky coffeetree (*Gymnocladus dioica*) were coated with either an adhesive plus hydrophilic gel, an adhesive only, or neither (control). The seeds were then planted in sand in the greenhouse, and irrigated at either 3-, 6-, or 9-day intervals. Percent germination of black locust and common honeylocust seeds irrigated at 3-day intervals was significantly decreased with exposure to hydrophilic gel. Gel-coated Kentucky coffeetree seeds irrigated at 6-day intervals also had a significantly lower percent germination than those treated with adhesive alone, but germination of untreated Kentucky coffeetree seeds was not significantly different than that of adhesive- or gel-coated seeds. No other significant difference in germination percentage was observed. Seedling heights and dry weights were not affected by seed treatment; however, decreased moisture availability due to longer time periods between irrigations tended to delay emergence and reduced seedling vigor.

Seeds treated with the same coatings as above were planted in the field where there were no significant effects on germination as a result of seed coatings with any of the species.

INTRODUCTION

Hydrophilic gels are compounds which, according to manufacturers, improve seed germination and seedling survival. These materials absorb many times their weight in moisture and release it as the environment becomes dry.

Hydrophilic gels can be used as a seed coating, as a fluid drilling medium, or incorporated into a plant growing medium. Studies examining the effect of hydrophilic gel coatings on seed germination and seedling growth have produced conflicting results. Seeds coated with a hydrophilic gel, then planted in strip mine soil had a higher initial germination rate than untreated seeds (3). Similarly, hydrophilic polymer seed coating enhanced germination of sweet corn (*Zea mays*) at 2.3 and 4.6 g/kg seed but not at 9.1 g/kg seed, while all levels of polymer coating had a negative effect on germination of cowpea (*Vigna unguiculata*) (1). No improvement was evident in emergence rate or total germination of Russian wildrye (*Elymus junceus*) coated with five different hydrophilic coatings (2).

Germination of pepper (*Capsicum annuum*) seed coated with clay or sand decreased except when seeds were placed in a high oxygen environment, indicating that coatings may reduce 0_2 movement into the seed (5, 6). When high concentrations of hydrophilic

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materials were used as seed coatings, the water holding capacity was increased but aeration was apparently diminished (1). Reduced seedling vigor of pregerminated snapdragon (*Antirrhinum majus*) seeds stored in hydrophilic gels correlated also with decreased oxygen diffusion rates through the material (3).

Other factors may also contribute to reduced germination rates in the presence of hydrophilic gels. According to Searle (7), a hydrophilic material absorbed water and seeds germinated, but the soil was too hard for root penetration and seedling death resulted. In this situation, it would be advantageous for the seed to remain quiescent until adequate moisture was available to sustain growth and root penetration.

The purpose of the present study was to determine whether hydrophilic gel applied as a seed coating results in improved seed germination and seedling survival.

METHODS

Greenhouse studies. Seeds of black locust (*Robinia pseudoacacia*), common honeylocust (*Gleditsia triacanthos*), and Kentucky coffeetree (*Gymnocladus dioica*) were coated with hydrophilic gel (a starch-graft copolymer of potassium polyacrylate and polyacrylamide) after pregermination requirements were met. Seeds were weighed and dipped in an adhesive (maltodextrin and water 1:1 wt/wt) at rates of: a) 1% by seed weight; and b) the maximum amount retained by seeds when placed in excess gel-talc mixture. Other seeds were treated with only adhesive. Seeds were planted in 10 cm plastic pots of washed sand and irrigated at 3-, 6-, or 9-day intervals. Each treatment contained 15 seeds and was replicated three times in a completely randomized design.

Seedling emergence was evaluated and recorded daily. Germination was considered complete when no further seedling emergence was apparent for 7 days. Seedling heights and dry weights were measured 28 days after planting.

Arc-sin transformations (8) were performed on all germination data, and analysis of variance and mean separation procedures were conducted to evaluate differences among hydrophilic gel treatments within each species and irrigation interval.

Field studies. Seeds of the same deciduous hardwoods were treated as previously described and planted on May 23 in a prepared field of Haynie very fine sandy loam. Each treatment contained ten seeds and was replicated four times. The plots received no fertilizer or supplemental irrigation prior to or during the study. Post-planting precipitation was as follows: May, 0.16 in. (1 incidence); June, 3.39 in. (11 incidences); July, 0.55 in. (1 incidence); August, 1.07 in. (5 incidences). Weeds were removed by hand as necessary.

Seedling emergence was evaluated daily until apparently com-

plete. Above-ground portions of plants were harvested 42 days after planting and dry weights determined after drying for 48 hr at 80°C. Statistical analyses were the same as those described above.

RESULTS AND DISCUSSION

Greenhouse studies. Percent germination of black locust seed irrigated at 3-day intervals was significantly greater in untreated seeds than in seeds treated with hydrophilic gel (Table 1). This trend was also apparent with 9-day irrigation intervals, although differences were not significant.

Table 1. Influence of seed coatings and 3-, 6-, and 9-day irrigation intervals on seedling emergence, average height (cm) and dry weight (g) of black locust. Data were taken 28 days after first seedling emergence.

	Seedling emergence (%)			Height (cm)		Weight (g)	
Treatment	3 day	6 day	9 day	3 day	6 day	3 day	6 day
Control	99.2a[z]	43.0a	43.6a	4.6a	3.0a	.04a	.02a
Adhesive only	91.3ab	46.7a	31.1a	4.5a	3.6a	.04a	.04a
1% hydrogel	84.5b	51.5a	16.4a	4.3a	3.7a	.04a	.03a
Excess hydrogel	83.2b	44.4a	4.4a	4.3a	3.5a	.05a	.04a
Overall mean	89.6A[y]	46.4B	23.9C	4.4A	3.4B	.04A	.03B

[z] Mean separation using Tukey HSD (.05). Means within columns followed by the same lower case letter are not significantly different.
[y] Mean separation using Tukey HSD (.05). Means within measurement parameters followed by the same capital letter are not significantly different.

The tendency for decreased emergence of treated seeds may be attributed to a decrease in aeration around these seeds, as indicated by Sachs, Cantliffe, and Nell (5, 6) with coated pepper seeds. Oxygen availability to the seed may have been reduced by the adhesive material and further inhibited by the addition of the gel material, particularly at the higher gel rate. Baxter and Waters (1) found that polymers had a beneficial effect on imbibition and germination of sweet corn at high water potentials, but this was reversed as water potentials increased.

Black locust seedling heights and dry weights were not significantly affected by any of the seed treatments (Table 1). Apparently, once the seed germinated, seed coating had no detrimental or advantageous effect.

Average emergence and growth of black locust seedlings were affected by irrigation interval (Table 1). Seedling emergence was significantly decreased as time between irrigations increased from 3 to 6 days and from 6 to 9 days. As expected, seedling heights and dry weights were also significantly decreased by reduced watering. Nine days between irrigations provided inadequate moisture for black locust seedling survival.

Germination of common honeylocust in response to seed treatment differed from that of black locust. Percent emergence was not significantly different for any seed treatment in any irrigation regime (Table 2). Seedling heights and dry weights also showed no significant differences between treatments.

Table 2. Influence of seed coatings and 3-, 6-, and 9-day irrigation intervals on seedling emergence, average height (cm), and dry weight (g) of common honeylocust. Data were taken 28 days after first seedling emergence.

	Seedling emergence (%)			Height (cm)		Weight (g)	
Treatment	3 day	6 day	9 day	3 day	6 day	3 day	6 day
Control	64.4[z]	44.1	5.7	10.7	9.3	0.14	0.13
Adhesive only	60.3	62.3	8.3	11.6	8.6	0.16	0.13
1% hydrogel	73.8	56.2	3.0	11.1	8.3	0.16	0.10
Excess hydrogel	60.3	60.6	2.4	10.4	8.4	0.16	0.10
Overall mean	64.7A[y]	55.8A	4.9B	11.0A	8.6B	0.16A	0.12B

[z] There were no significant differences among treatments within each irrigation treatment in any measurement parameter (F-test, .05).
[y] Mean separation using Tukey HSD (.05). Overall means within measurement parameters followed by the same capital letter are not significantly different.

As with black locust, decreased irrigation frequency delayed seedling emergence of common honeylocust, although the delay was not significant until exposed to 9 days between irrigations (Table 2). Seedling heights and dry weights were significantly decreased with longer intervals between water applications. Inadequate moisture was available for honeylocust survival with 9-day irrigation intervals.

Percent emergence of Kentucky coffeetree seed followed no consistent trends in any irrigation regime (Table 3). Hydrophilic gel-

Table 3. Influence of seed coatings and 3-, 6-, and 9-day irrigation intervals on seedling emergence, average height (cm), and dry weight (g) of Kentucky coffeetree. Data were taken 28 days after first seedling emergence.

	Seedling emergence (%)			Height (cm)			Weight (g)		
Treatment	3 day	6 day	9 day	3 day	6 day	9 day	3 day	6 day	9 day
Control	95.6a[z]	89.1ab	64.6a	10.2a	10.5a	9.8a	0.8a	0.29a	0.25a
Adhesive only	93.4a	91.3a	94.9a	10.6a	10.8a	10.8a	0.51a	0.33a	0.33a
Excess hydrogel	98.5a	78.2b	91.3a	10.2a	10.8a	10.8a	0.49a	0.33a	0.34a
Overall mean	96.1 A[y]	86.2A	83.6A	10.3A	10.7A	10.5A	0.49A	0.32B	0.31B

[z] Mean separation using Tukey HSD (.05). Means within columns followed by the same lower case letter are not significantly different.
[y] Mean separation using Tukey HSD (.05). Means within measurement parameters followed by the same capital letter are not significantly different.

coated seeds at 6-day irrigation intervals had a significantly lower percent germination than seeds treated only with adhesive, but percent emergence of untreated seeds was not different than gel- or adhesive-treated seeds. As in other species, Kentucky coffeetree seedling heights and dry weights did not significantly differ among treatments within an irrigation interval (Table 3).

In contrast to other species, no significant differences in percent emergence of Kentucky coffeetree seeds occurred among irrigation regimes. Seedling heights also did not differ among irrigation schedules; however, dry weights of plants irrigated at 3-day intervals were significantly greater than those irrigated at 6- or 9-day intervals.

Seed size appeared to have an effect on seedling ability to survive low moisture levels (Table 4). Black locust, a small seeded species, was less tolerant to lower moisture levels than common honeylocust, a species with larger seeds. Kentucky coffeetree, a species with very large seeds survived all irrigation regimes tested. Therefore, larger seeds may retain higher moisture levels and better support seedling growth and development for a limited time after germination.

Table 4. Average percent emergence of seeds of 3 woody species exposed to 3-, 6-, or 9-day irrigation intervals.

	Irrigation interval (day)		
Species	3	6	9
Black locust	89.6a	46.4b	23.9c
Common honeylocust	64.7a	55.8a	4.9b
Kentucky coffeetree	96.1a	86.2a	83.6a

[z] Mean separation using Tukey HSD (.05). Means within species followed by the same letter are not significantly different.

Field studies. There were no significant differences in seed germination of any of the species tested due to treatment (Table 5). There were also no significant differences between shoot dry weights among seed coatings of any species.

Table 5. Percent germination of seeds of three woody legumes when planted in the field after treatment coating with sticker and hydrogel. There were no statistical differences (F-test, .05) in germination due to seed treatments.

	Species		
Treatment	Honeylocust	Black locust	Kentucky coffeetree
Control	52.5	40.0	82.5
Sticker	62.5	52.5	82.5
1% hydrogel	67.5	32.5	—
Excess hydrogel	60.0	27.5	67.5

SUMMARY

These studies indicate that hydrophilic gels utilized as seed coatings do not consistently or significantly improve seed emergence or subsequent seedling vigor of the plants tested. They may, in fact, inhibit or delay emergence by reducing aeration around the imbibing or germinating seed.

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THE ROLE OF PLANT PROPAGATION IN THE PLANT BREEDING PROGRAMS OF THE U.S. NATIONAL ARBORETUM

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Plant propagation plays a vital role in every facet of the tree and shrub breeding programs at the U.S. National Arboretum (USNA). Although the Arboretum employs most commercial propagation methods, the way in which they are used and the plant materials involved make for a very unique propagation program.

The tree and shrub breeding projects of the USNA have been of particular interest to the members of the IPPS and other plant industry associations. The USNA has strived to introduce to the nursery trade plants with improved horticultural characteristics, which are most often meant to rectify deficiencies found in the list of available cultivated plants. The improved trait of a new plant may range from such functional characteristics as increased disease resistance to visual attributes such as novel flower color.

The main role of the shrub breeding project, led by Dr. Donald Egolf and described in previous papers (2, 3), has traditionally been the introduction of new cultivars. Mr. Gene Eisenbeiss has led the holly (*Ilex*) project. Its main emphasis have been on hybridization to improve the available germ plasm and on holly taxonomy. The tree breeding project, initiated by Dr. Frank S. Santamour, Jr. (recently joined by Dr. Alden Townsend) has been broader in scope; only recently has cultivar introduction become a priority. Previous papers describe the USNA's introduction program and research goals (1, 4, 5).

Vegetative propagation by cuttings is by far the most important propagation method used in selection programs. In turn, the process of selection, the simplest means of genetic improvement, is the most important technique used in the USNA programs. Selection is the technique whereby wild or cultivated, existing plants are screened for new and desirable horticultural characteristics. A selection may be an isolated plant or an individual in the midst of a large seedling population.

Once an individual with potential has been recognized, it must be thoroughly evaluated. Evaluation is the beginning of a long process, involving propagation at many steps along the way. The Arboretum must first propagate enough plant material to be sent out to cooperators for evaluation. Generally, the propagation must be in the form of cuttings, since grafted or budded plants could cause a mix-up (i.e. the living rootstock under a dead scion might

inadvertently be evaluated). A small number of rooted cuttings are all that are required at this stage. However, obtaining even a small number of a difficult-to-root plant can cause frustration and delay!

After a selection has undergone evaluation and the decision has been made to continue towards its release, another group of rooted cuttings must be sent to wholesale propagating cooperators. These cooperators may propagate the new plant by any feasible method which facilitates stock increase in anticipation of future sale. After an adequate supply of ramets has been propagated by the stock increase nurseries, the originator at the Arboretum assigns the plant a legitimate cultivar name and registers the name with the International Registration Authority for the particular genus. An official release notice is formulated through the Agricultural Research Service (ARS) of the U.S. Department of Agriculture. The wholesale cooperators are responsible for the release of the new cultivar to other wholesale and retail nurseries. The Arboretum will often supply additional propagations to other public or research (non-commercial) facilities.

Propagation by cuttings is also central to a more complex method of cultivar development—hybridization. This differs from the previous process only in how the potential new cultivar is created. Beginning with the evaluation by cooperators the steps are virtually the same until the plant's final release. Compared to simple selection, many more steps of propagation may be required in this type of breeding program.

A much-simplified example can be described as follows. Two parent plants are selected, each with a unique superior trait. The parents are selected with the intent that the combination of their characteristics would create a highly desirable plant. Through some means of controlled cross-pollination the two parent plants are hybridized. This process may be very complex, depending on many factors that include flower type, flowering time, and sexual compatibility. It is always prudent to propagate the parent plants (vegetatively) at the initiation of the project to insure against loss if the hybridization needs repeating in subsequent years; parent plants also serve as references for comparison with the progeny.

If all goes as planned, seeds will develop on the plant used as a female. These seeds provide the next generation of plants. Many times very few seeds develop, which makes this propagation step crucial; it must be done carefully to avoid losing any viable seed.

It should be noted that with interspecific crosses, it is necessary to determine whether the resulting seedlings are true hybrids. If morphological features are very distinct, hybridity may be assumed from morphological characteristics. Chemical methods and chromosome counts, when applicable, are more reliable characteristics upon which to base hybridity. As the progeny grow, several may be selected for continued evaluation.

These preliminary selections are propagated by cuttings and sent to cooperators for evaluation. It is easy to see that the process of selection is involved in any introduction of a new cultivar whether or not controlled pollination is employed. After cooperator evaluations, a final choice is made by the originator and the resulting cultivar is propagated in sufficient numbers to be sent out to wholesale cooperators for stock increase. Both the evaluation by selected cooperators and the propagation by wholesale cooperators are mediated by legal agreements, namely the "Standard Memorandum of Understanding for Evaluation of Potential New Cultivars of Ornamental Shrubs and Trees" and "Standard Memorandum of Understanding for Increasing the Planting Stock of Vegetatively Propagated Stock."

A good example of a hybridization program done at the USNA is the work that resulted in the release of two *Platanus* (planetree) cultivars in 1984 (6). 'Liberty' and 'Columbia' originated from crosses made in 1968 and 1970 respectively, between *P. orientalis* L. and *P. occidentalis* L.; the same species are the parents of the so-called "London" plane (*P.* ×*acerifolia* (Ait.) Willd. or *P.* ×*hispanica* Muenchh.). The goal of the project was to combine the disease resistance (sycamore anthracnose) of *P. orientalis* with the hardiness and growth form of *P. occidentalis*. Several hundred seedlings from the controlled pollination were planted out where natural infection by the anthracnose fungus (*Gnomonia platani* Kleb.) could occur. Four clones were selected for their resistance after 2 years of anthracnose infection. All four were also found to show strong compartmentalization of wounds (7) against decay organisms. These were propagated by cuttings and planted out again in field and roadside tests.

'Columbia' and 'Liberty' were selected for their superior growth and appearance. Two plants were named since each may respond differently to other pests and diseases and to various planting sites (6). The introduction process, from pollination to release to wholesale propagators, took 14 to 16 years, a time interval quite common in such a breeding program.

In addition to propagation by cuttings, seed propagation may play a major role in a USNA breeding program. As mentioned previously, seed resulting from controlled pollinations must be harvested, stored, and germinated for progeny testing. Also, potential germplasm for future breeding work is sometimes found on seed lists through the Index Seminum (a world-wide cooperative seed distribution program among arboreta and botanic gardens). Plant exploration trips often bring seed to be evaluated for future use. The seed are typically from uncommon plants and must be handled with utmost care.

In general, the National Arboretum does very little large-scale propagation. However, most propagation projects are crucial in the

outcome of Arboretum breeding programs. Each step along the path to the release of a new cultivar requires some type of propagation and successful propagation is essential to the final goal.

The following list represents the most recent compilation of cultivar releases from the U.S. National Arboretum breeding programs:

Buxus microphylla var. *japonica* (Muell.-Arg.) Rehd. & Wils. 'Morris Dwarf', 'Morris Midget', 'National'

Camellia 'Ack-Scent', 'Ack-Scent Pink', 'Ack-Scent Red', 'Ack-Scent Sno', 'Ack-Scent Spice', 'Ack-Scent Star', 'Ack-Scent White', 'Cinnamon Cindy', 'Fragrant Joy', 'Fragrant Pink', 'Fragrant Pink Improved', 'Frost Prince', 'Frost Princess', 'Sunworshiper', 'Two Marthas'

Camellia japonica L. 'Frost Queen'

Clematis viticella L. 'Betty Corning'

× *Cupressocyparis leylandii* (A.B. Jacks & Dallim.) Dallim & A.B. Jacks. 'Silver Dust'

Eurya japonica Thunb. 'Winter Wine'

Hibiscus rosa-sinensis L. 'Vulcan'

Hibiscus syriacus L. 'Diana', 'Helene'

Ilex 'Accent', 'Apollo', 'Clusterberry', 'Elegance', 'John T. 'Morris', 'Lydia Morris', 'Oriole', 'September Gem', 'Sparkleberry', 'Tanager'

Ilex × *attenuata* Ashe 'Sunny Foster'

Ilex crenata Thunb. 'Highlight', 'Twiggy'

Ilex × *koehneana* Loes. 'Jade', 'Ruby'

Iris kaempferi Siebold ex Lem. 'Blue Zebra', 'Capitol Dandy', 'Enduring Pink Frost', 'Grape Fizz', 'Lasting Pleasure', 'Lavender Krinkle', 'Pink Bunny', 'Royal Fireworks', 'Sky and Mist', 'Violet Vase', 'White Profusion', 'Wine Ruffles'

Kalmia latifolia L. 'Bettina'

Lagerstroemia × 'Muskogee', 'Natchez', 'Tuscarora', 'Acoma', 'Hopi', 'Pecos', 'Zuñi', 'Tuskegee'

Lagerstroemia indica L. 'Catawba', 'Cherokee', 'Conestoga', 'Potomac', 'Powhatan', 'Seminole'

Magnolia × 'Ann', 'Betty', 'Freeman', 'Galaxy', 'Jane', 'Judy', 'Maryland', 'Nimbus', 'Pinkie', 'Randy', 'Ricki', 'Spectrum', 'Susan'

Malus sieboldii (Regel) Rehd. 'Fuji'

Metasequoia glyptostroboides H. H. Hu & Cheng 'National'

Platanus × 'Columbia', 'Liberty'

Pyracantha × 'Mohave', 'Navaho', 'Shawnee', 'Teton'

Pyrus calleryana Decne. 'Capital', 'Whitehouse'

Rhododendron × 'Bowie', 'Pryored'

Rhododendron austrinum (Small) Rehd. 'Yellow River'

Rhododendron bakeri (W. P. Lemm. & McKay) H. Hume 'Camp's Red'

Rhododendron prunifolium (Small) Millais 'Hohman'

Ulmus × 'Homestead', 'Pioneer'

Ulmus parvifolia Jacq. 'Dynasty'

Viburnum × 'Chesapeake', 'Eskimo', 'Oneida'

Viburnum × *burkwoodii* Burk. & Skip. 'Mohawk'

Viburnum × *carlcephalum* Burk. ex Pike 'Cayuga'
Viburnum dilatatum Thunb. 'Catskill', 'Erie', 'Iroquois'
Viburnum lantana L. 'Mohican'
Viburnum plicatum Thunb. forma *tomentosum* (Thunb.) Rehd. 'Shasta', 'Shoshoni'
Viburnum rhytidophylloides Suringar 'Alleghany'
Viburnum sargentii Koehne 'Onondaga', 'Susquehanna'
Viburnum sieboldii Miq. 'Seneca'

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Thursday Evening, December 11, 1986

The thirty-sixth annual banquet was held in the Aztec Room of the Hershey Lodge, Hershey, Pennsylvania.

On behalf of the Society, the research award was presented to Dr. Dennis Stimart, Department of Horticulture, University of Wisconsin at Madison by Dr. Paul Smeal.

Dr. Leonard P. Stoltz made the following IPPS Eastern Region Award of Merit presentation:

AWARD OF MERIT

Our Award of Merit recipient came from a family of small farmers. His life upholds the old adage "You can take the boy away from the farm, but you can't take the farm away from the boy!"

After graduation from high school he entered the army and spent 3 yr in Europe where he became an expert in artillery, travel, and poker—his expertise, however, was not necessarily in that order. With 3 yr of expertise behind him in dealing with numbers and juggling the probabilities of poker he decided to enter Ohio University in 1946 to become an accountant. Upon graduation in 1949 he decided not to become an accountant but entered Stanford Graduate School of Business and graduated in 1951. Being an inveterate gambler and wanting to play for higher stakes but with someone else's money he joined a Wall Street firm as an investment counselor. After 10 years in this position he left to become manager of the Personal Investment Division of another Wall Street firm.

In 1964 the frustrations of picking the right stocks, selling out the unproductive ones, and the volatility of the Wall Street market induced our Awardee to search for a new profession—he longed to get back to the farm and experience **the sedate life** of the nurseryman farmer. In late 1965 he put a binder on a piece of farm land and in July, 1966 he said goodbye to Wall Street, packed up his family, and moved to the country.

Our Awardee joined our Society as a junior "partner" at the 1966 meeting in Newport. He was so impressed and enthused by the events of this meeting that, much to the distress of his family, on that Christmas eve he was "Ho-Ho-Hoing" and sticking cuttings under an electric light in his first real propagating house.

With this new beginning and with a small number of stocks our Awardee found he was still trying to pick winning stocks, trying to accumulate more of them (through propagation), still trying to sell off the unprofitable ones, and he still had to contend with the volatility of the marketplace. He has since come to realize that in his new profession he now has another unpredictable variable to contend with—Mother Nature. Paradoxically, the vicissitudes of Wall

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Street kept him constantly frustrated and unhappy while similar problems and uncertainties of the professional propagator have provided him the quietude and satisfaction he was seeking.

Our Awardee is not above insider trading, in fact, he has participated in it each year, willingly trading stock or information with his fellow insiders at these meetings. Through this insider trading he was able to accomplish a very successful merger. He has merged the boy, the farm, and business to produce an outstanding professional propagator.

Ladies and Gentlemen I present to you the 1986 Eastern Region IPPS Award of Merit recipient, James (Jim) E. Cross.

Friday Morning, December 12, 1986

The Friday morning session convened at 8:00 a.m. with Peter Vermeulen serving as moderator.

CYTOKININ CONSUMPTION BY MICROPROPAGATED SHOOTS

JOHN W. EINSET
Arnold Arboretum
Harvard University
Cambridge, Massachusetts 02138

Abstract. When shoots of *Actinidia kolomikta* were cultured on a basal medium supplemented with 30 μM N^6-(Δ^2-isopentenyl)adenine (i^6Ade), cytokinin was rapidly consumed from the medium at a rate corresponding to 100±23 nanomoles i^6Ade per g FW per day. At the same time, zeatin (io^6Ade) was excreted into the medium where it reached a level of approximately 8μM during 10 days of incubation. Rates of i^6Ade consumption, expressed as nanomoles consumed per g FW per day, for shoot cultures of other species were as follows: *Actinidia arguta*, 160±23; *Magnolia* × *soulangiana*, 18±3; *Metasequoia glyptostroboides*, 120±43; *Nicotiana tabacum*, 33±8; *Paulownia coreana*, 130±30; *Sassafras albidum*, 53±11; *Syringa* × *hyacinthiflora*, 62±10. Based on these consumption rates, one can expect that if one uses standard procedures for micropropagation (e.g. 30 μM i^6Ade, 20 ml per tube), the medium will become totally depleted of cytokinin within about 3 to 10 weeks depending on the species.

INTRODUCTION

Because cytokinin treatments are fundamental to micropropagation by shoot multiplication (1,4,7), improvements in technology will undoubtedly depend on advances in the basic understanding of these important phytohormones. During the last 3 yr, we have taken

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advantage of the experimental characteristics of *Actinidia* species to develop well-defined hypotheses with regard to the biosynthesis of cytokinins, in particular, the metabolic pathway producing cytokinin (2) and the sites of biosynthesis within plants (3).

Theoretically, when one uses cytokinin as a growth regulator for micropropagation, one elevates the internal phytohormone level of shoots to cause controlled sympodial growth. At the end of each passage *in vitro,* clusters of shoots are subdivided and the individual branches are used either for further shoot multiplication or for the production of plantlets after inducing roots on cuttings with an auxin treatment. When utilized with responsive plants, these manipulations have the potential to result in a million-fold clonal multiplication of desirable individuals in less than a year.

In view of the obvious importance of micropropagation to horticulture, surprisingly little is known about the cytokinin status of propagules growing *in vitro*. Following an earlier determination of the "critical cytokinin concentration" in actively growing *Actinidia* shoots (1), this report examines *in vitro* cytokinin consumption by several woody species, including *Actinidia,* by monitoring the disappearance of phytohormone from the medium using HPLC. The results confirm the earlier finding of a substantial cytokinin requirement by micropropagated shoots in the range from 18 to 160 nanomoles per g fresh weight per day, depending on the species. Determining the exact cytokinin requirement of growing shoots is an important step in understanding the nutritional basis of micropropagation and in designing improved methods for unresponsive species (1).

MATERIALS AND METHODS

Shoot cultures of the following species have been maintained for 1 to 3 years with monthly passage onto a basal medium supplemented with cytokinin: *Actinidia arguta, A. kolomikta, Magnolia* × *soulangiana, Metasequoia glyptostroboides, Nicotiana tabacum* cv. Wisconsin #38, *Paulownia coreana, Sassafras albidium, Syringa* × *hyacinthiflora* cv. Excel (5). In all cases the basal medium contained inorganic (8) and organic (6) constituents as specified plus 5 mg/l nicotinic acid and 5 mg/l pyridoxine HCl. Media for stock cultures of *S. albidium* and *S.* × *hyacinthiflora* contained supplements of either 33 μM N^6-benzyladenine plus 0.6 μM indole-3-acetic acid or 2.2 μM thidiazuron, respectively. All other shoot cultures were maintained with basal medium plus 30 μm N^6-(Δ^2-isopentenyl)adenine (i^6Ade).

When cytokinin consumption was studied, shoots were transferred from stock cultures to basal medium (20 ml per tube) containing 30 μm i^6Ade. After 20 days incubation at 27°C with a 16 hr light (40 to 65 $\mu Em^{-2}s^{-1}$) and 8 hr dark photoperiod, the growing

shoots were moved to tubes containing 2 ml of liquid medium consisting of the basal constituents plus 30 μM i^6

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RESULTS AND DISCUSSIONS

The *Actinidia* system. Among the many advantages of *Actinidia* as an experimental subject for cytokinin studies is the fact that the phytohormone levels of tissues can be determined rapidly and definitely using straightforward HPLC methodology. By exploiting this characteristic of *Actinidia*, we have developed well-defined concepts about the mechanism (2) and sites of cytokinin production (3) in this plant. As indicated in the proposed scheme (Fig. 1), the cytokinin zeatin (io^6Ade) is formed by the 0_2-dependent hydroxylation of i^6Ade which, in turn, is produced in 2 steps from AMP with i^6AMP as an intermediate: AMP → i^6AMP → i^6Ade → io^6Ade. This pathway appears to be localized in roots and in the region of cellular differentiation behind the growing tip in the stem on the basis of an extensive analysis of the distribution of i^6Ade hydroxylase within plants (3).

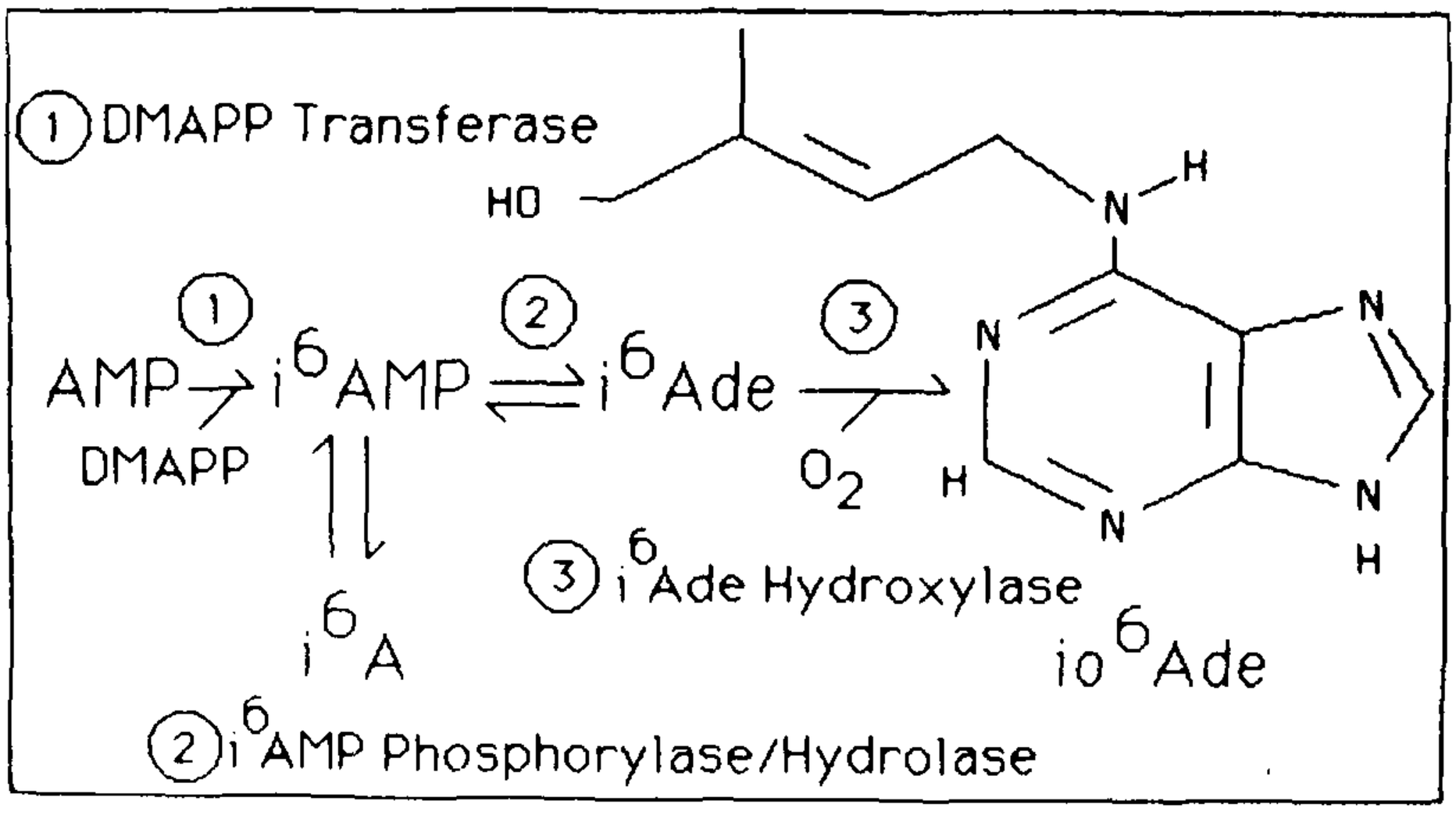

Figure 1. Proposed mechanism for cytokinin biosynthesis in *Actinidia*

Using i^{6}Ade as the cytokinin supporting *in vitro* shoot growth and multiplication, we have determined phytohormone consumption rates by various plant tissue cultures. As Fig. 2 shows, shoots of *A. kolomikta* rapidly depleted the i^{6}Ade content of the medium when they were incubated with 30 μM i^{6}Ade. Within 2 days the i^{6}Ade concentration of the medium had declined to about 20 μM and i^{6}Ade was almost totally consumed by 6 to 8 days. From the data in Fig. 2 and similar experiments, the rate of i^{6}Ade consumption by *A. kolomikta* is calculated to be 100±23 nanomoles per g FW per day. Not surprisingly, based on the biosynthetic pathway for cytokinin in this plant, *A. kolomikta* shoots excreted io^{6}Ade into the medium as they grew in the presence of i^{6}Ade.

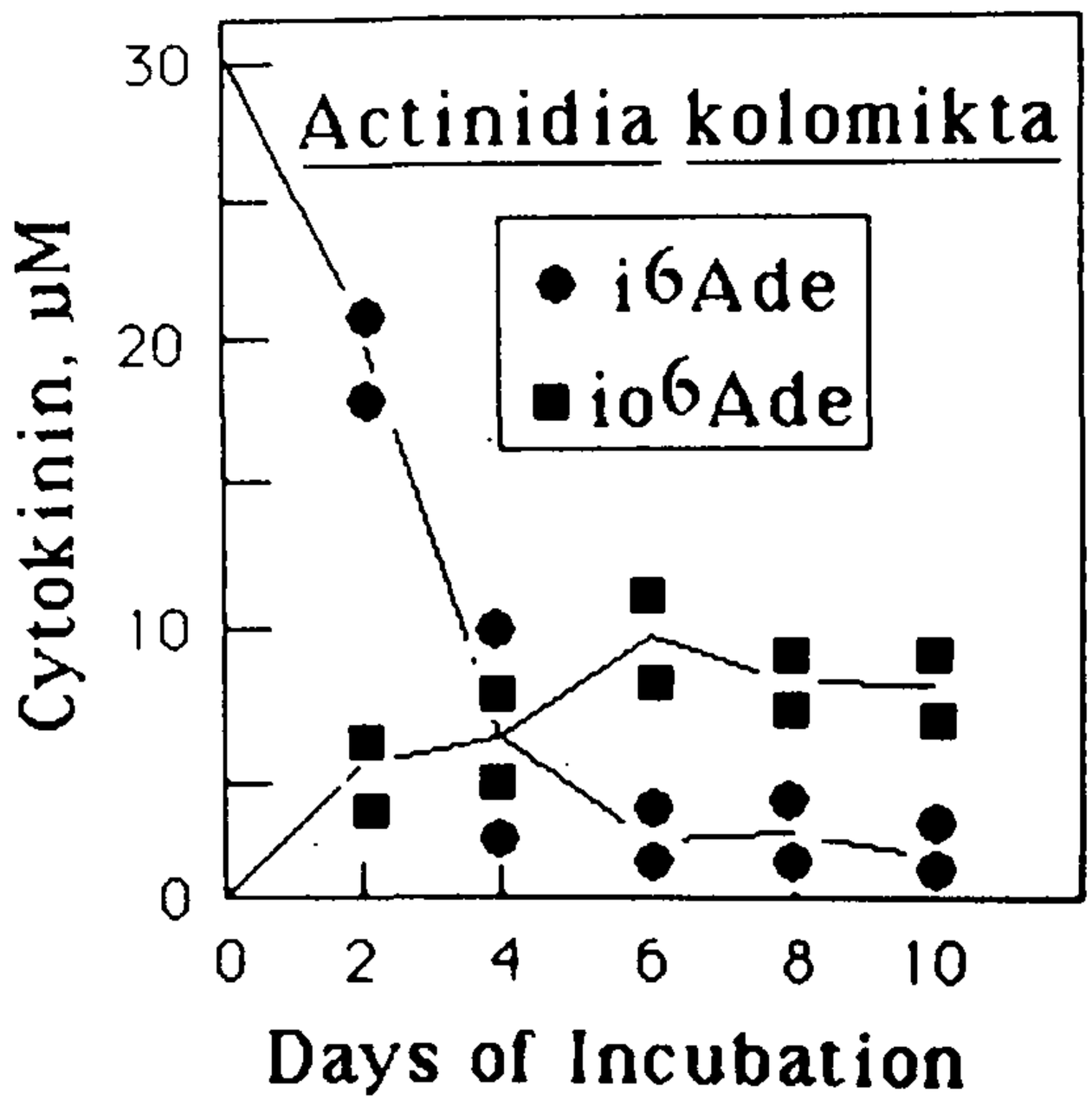

Figure 2. Cytokinin concentrations in nutrient medium supporting the growth of *Actinidia kolomikta* shoots.

Comparative cytokinin consumption. Table 1 lists i^{6}Ade uptake rates by shoot cultures of several different species. Rates of consumption ranged from a maximum corresponding to 160 nanomoles per gFW per day for *A. arguta* to a low of 18 nanomoles per gFW per day for *M. soulangiana*. Interestingly *M.* ×*soulangiana* had the slowest growth rate of any of the plants studied. On the other hand, *N. tabacum*, which was the most rapidly-growing species, also had a low rate of i^{6}Ade consumption. There did not appear, therefore, to be a clear-cut relationship between growth rate and cytokinin consumption by shoots. As expected (2), both species of *Actinidia*, as well as *S.* ×*hyacinthiflora*, excreted io^{6}Ade into the medium during growth on i^{6}Ade.

Table 1. *Cytokinin consumption rates by micropropagated shoots growing in a nutrient medium supplemented with 30 μM i⁶Ade. Stock cultures were subdivided and individual shoots (0.1 g per shoot) were transferred to fresh medium as described; in each case values are means of at least 4 independent determinations ± SE.*

Family	Species	Rate of i⁶Ade Consumption (nmoles/gFW/day
Taxodiaceae	*Metasequoia glyptostroboides*	120±43
Magnoliaceae	*Magnolia × soulangiana*	18±3
Lauracae	*Sassafras albidum*	53±11
Actinidiaceae	*Actinidia arguta*	160±50
	Actinidia kolomikta	100±23
Oleaceae	*Syringea × hyacinthiflora*	62±10
Solonaceae	*Nicotiana tabacum*	33±8
Scrophulariaceae	*Paulownia coreana*	130±30

SUMMARY

Cytokinin consumption rates can be used to determine the phytohormone concentrations needed by shoot cultures. For example, given an uptake rate of 160 nanomoles per gFW per day (*A. arguta*) and an increase in fresh weight corresponding to a doubling per week, a typical micropropagated shoot (0.1 g) would deplete the cytokinin in 20 ml of 30 μM i⁶Ade within 18 days. Under the same conditions, shoots with consumption rates corresponding to 150, 100,50 and 25 nanomoles per g FW per day would deplete the i⁶Ade in a standard medium in 20, 28, 56 and 112 days, respectively. Thus, it is probable that, in several instances, micropropagators transfer their shoot cultures to fresh medium long after the cytokinin in the medium has been exhausted. The so-called "maturation" phase of tissue culture growth, for example, conceivably could involve a period of cytokininless development.

Unfortunately, cytokinin consumption rates reveal little about the biochemistry involved in cytokinin action. It is not possible, for example, to know the exact amount of phytohormone that the plant actually uses in meeting its nutritional requirement for cytokinin since only a fraction of the amount consumed may be utilized internally. Nevertheless, a daily rate of cytokinin consumption of 100 to 160 nanomoles per g FW determined for *Actinidia* is in the range expected for a "critical concentration" corresponding to 150 nanomoles io⁶Ade per g FW (1). This rate is also consistent with estimates of the rate of cytokinin disappearance from within shoots that were transferred from stock cultures to cytokininless mediums.

Having developed the technology to study cytokinin consumption by micropropagated shoots and having determined the rates of i⁶Ade uptake by several species that can be grown successfully *in vitro*, we are now at the stage to test some possible explanations

why some woody species are not responsive (1): that is,

1) The cytokinin requirement of non-responsive explants is greater than the amount supplied in the medium.
2) Non-responsive explants fail to assimilate cytokinin from the medium.

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QUESTION BOX

The Question Box Session was convened at 9:00 a.m. with Joerg Leiss and Bruce Briggs serving as moderators.

MODERATOR LEISS: We have yellow nutsedge and are not in a position to move our nursery. I understand that Roundup will only burn off the tops and set the nuts into dormancy for one or more seasons. I've also read that Besagran applied when new growth is 4 to 6 in. tall will kill both top growth and nutlets. Can anyone comment on these herbicides?

PHILIP CARPENTER: Roundup is not an effective control. Besagran is an effective control but it has no woody ornamental clearances on the label. I cannot recommend it on that basis.

MODERATOR LEISS: Question for Philip Carpenter on the fumigation of liner beds. The labels on most brands of methyl bromide list application rates between 1 and 4 lb/100 sq. ft. In light sandy soils at what rate can we expect control of wild chrysanthemum and yellow nutsedge. Also at the higher rates, do we chance eliminating beneficial soil fungi and organisms?

PHILIP CARPENTER: You should have a real concern about what you will be doing to the soil mycorrhizal fungi. Growers should always check the growth of their seedlings after fumigation. Soil fumigation will not be effective for nutsedge control because nutlets can be found down 3 and 4 ft in the soil. Soil fumigation is generally only effective from 6 to 8 in. maximum. With wild chrysanthemum, fumigation will be fairly effective because the rhizomes are found in the top few inches of the soil.

HENRY CLARK: For 2 years we fumigated our soil and we had to come back into that soil and inoculate with nonfumigated soil.

MODERATOR LEISS: Can someone comment on the use and effectiveness of the fumigant, Basamid?

PHILIP CARPENTER: The soil needs to be moist and also warm.

JOERG LEISS: Ralph Shugert recommends 300 lb/acre and temperature of 50°F. For seed beds, September is best and with liners—spring (April), is best. He also recommended following the instructions which are very detailed. (Editor's note: Besamid is not registered for use in the U.S.)

MODERATOR LEISS: Are there fungal problems associated with the use of thermal blankets? What preventative treatments are being used?

DICK BIR: Yes, there are fungal problems, In our area container growers use whatever is labeled for *Botrytis* and they feel comfortable using it. In our area generally Benlate is used. Just spray the containers down, let them dry and cover.

CLAYTON FULLER: We have few fungal problems but are on a Ziram spray program. If your plants are clean when they go under

you do not have much of a problem. You can run into a lot of problems if you don't wait till the leaves have dropped before tipping and covering.

MODERATOR LEISS: A question for Peter Vermeulen. Your paper on container configuration showed interesting data on temperatures in round vs. hexagonal pots but did not tell us whether there were differences in cold damage. Did the plants in hexagonal containers survive the cold better? If so, please give some typical numbers. Also, since the temperatures seemed to be so close in the two situations, do you feel that some factor other than temperature might account for survival, instead?

PETER VERMEULEN: We did not notice any difference in root survival. The research failed to show the temperature differential that we had originally observed when it was repeated.

MODERATOR BRIGGS: Question for Michael Dodge. Please list *Bruckenthalia, Erica carnea,* and *Calluna vulgaris* in terms of cold hardiness from hardiest to least hardy.

MICHAEL DODGE: *Phyllodoce* spp., *Erica carnea, E. tetralix, Calluna vulgaris, E.* × *darleyensis, E.* × *williamsii, E. cinerea, Bruckenthalia, E. ciliaris, Daboecia cantabrica.*

MODERATOR BRIGGS: What cover crops are best to renew soil after B&B.

TOM VANICEK: We use buckwheat and harrow it in 2 or 3 times in the summer. Sorghum is also a possibility. We over-winter with rye or, if we have young plants, oats are planted.

MICHAEL DODGE: For the summer we use Sudan grass. It is good for shading out summer perennial weeds.

PETER VERMEULEN: Be sure to use summer oats for fall planting so they will die during the winter.

BRUCE BRIGGS: In the west we have found that if you use a lot of herbicides that oats may be difficult to establish.

MODERATOR BRIGGS: How do you prune *Kalmia* to get them more compact?

JIM CROSS: One good time to prune is at the end of the winter if they are container-grown. In the summer after the buds have set is another good time.

WAYNE MEZITT: We prune after they finish flowering. It is always best to prune when young to induce branching close to the ground.

MODERATOR BRIGGS: How do you prevent damage on azaleas from Surflan?

BRUCE BRIGGS: We had reduced growth problems with it on some azaleas. It appears to depend on the cultivar.

MODERATOR BRIGGS: Does anyone have a comment on the compacting of coarse sand around cuttings by hammering rather than just watering the cuttings into the medium.

JIM CROSS: We just water the cuttings into the medium. With

sharp sand it may be O.K. to hammer the cuttings into the medium, but with round sand it could be a problem.

MODERATOR BRIGGS: Does anybody use an atomizing fogger and how well does it work?

JIM CROSS: For a propagator with only one propagating house it presents a problem because flexibility is reduced. However, the little sonic types that cost under $100 could be tried if you section off part of a greenhouse.

CAMERON SMITH: Harold Pellett is using ultrasonic humidifiers in tents with good results.

MODERATOR BRIGGS: Can heather be propagated by micropropagation.

BRUCE BRIGGS: Yes, we have done them. However, they are very easy to root, so why use micropropagation.

MODERATOR BRIGGS: Do *Picea* and *Pinus* grafts heal better when covered with wax or buried in moist peat?

JIM WELLS: I think waxing is the best method.

BILL VANDERKRUK: We do not wax but bury the unions in a mixture of peat and perlite.

GEORGE OKI: I agree. The cost to wax far exceeds the cost of just plunging in peat and perlite.

MODERATOR BRIGGS: Question for Jim Wells. What is the potting compost you use for your bulbs?

JIM WELLS: Make sure it is well drained. I use a light sandy soil that I sterilize with Vapam and mix 7 parts of it with 4 parts of grit, and one part of Promix. This year I changed because last year I obtained excess top growth. Now I mix equal parts of grit and sandy soil. The bulbs do not grow well in a very rich mixture. If you find that they are not growing as vigorously as you would like give them a little 20:20:20 after they flower.

MODERATOR LEISS: Question for Jim Wells? Are the majority of your bulbs hardy enough for outdoor culture in USDA Zone 5?

JIM WELLS: They are fundamentally hardy except for a few types. However, the very early blooming habit will force you to grow indoors.

MODERATOR LEISS: Question for Jim Wells? How do you germinate your narcissus seeds?

JIM WELLS: Just soak them in water and stand back.

MODERATOR LEISS: Question for Mike Dirr. Has there been any work done with K-IBA on *Juniperus procumbens* 'Nana'?

MIKE DIRR: Yes, it works very well. You can buy K-IBA from Research Organics Inc., Cleveland, Ohio.

MODERATOR LEISS: Question for Mike Dirr. Is there any significant damage done by ethanol to the cuttings of any species that would dictate a switch to a water based (K-salt) solution for that species? What species are affected?

MIKE DIRR: It is very dependent on species and time of year. I don't think anyone has assembled a list of those that are. I know that minature roses are among the most sensitive.

MODERATOR BRIGGS: Question for Jeremy Wells. Did you change the size, grade, and age of the plant material you are selling? Have you changed the type of retail outlet you are selling to or through?

JIM WELLS: Yes to both questions. He analyzed the market and found that there was a market not being served; and that is what has turned his business around.

MODERATOR BRIGGS: What is the effect of fertilizers on mycorrhizae?

LARRY KUHNS: Nitrogen, is not going to have much effect on the infection, but phosphorus will. High levels of fertilizer inhibit infection.

MODERATOR BRIGGS: Would fall incorporation of mycorrhizal inoculum into seed beds be effective for spring germinating seeds?

LARRY KUHNS: Infection is best in the spring when growth is starting.

MODERATOR BRIGGS: How does one root Douglas fir cuttings?

BRUCE BRIGGS: It is being rooted in the west. There are two or three things to remember: 1) take cuttings after they have gone through a cold period (January), 2) use a well drained mix, and 3) don't let them get too warm.

MODERATOR BRIGGS: *Prunus* × *cistena* and *P. triloba* 'Multiplex' cuttings are reported best taken early. How early is early and should the tip be left in?

BRUCE BRIGGS: Take the growing tip when soft and include an actively growing tip.

MODERATOR BRIGGS: What causes a cutting to callus heavily, but not root?

BRUCE BRIGGS: We have found several causes. The hormones are usually too strong or the rooting environment is too hot and that stresses the cuttings.

MIKE DIRR: Too low a hormone can also cause callus with a plant such as *Photinia*. I have heard from some southern growers that too much water can cause excess callus.

BRUCE BRIGGS: With *Photinia*, excess moisture improves rooting.

MODERATOR BRIGGS: Do fungicides applied before or after the cutting is stuck adversely affect rooting?

BRUCE BRIGGS: I know that Terrachlor has been bad.

JIM WELLS: Benlate in the rooting powder will elimate callus formation but allow rooting to occur.

MODERATOR BRIGGS: Why do cuttings decay? What are the

most common causes?

PETER VERMEULEN: The water-oxygen relationship is an important factor. Therefore, a well drained medium is important. A sterile medium is another important factor.

BRUCE BRIGGS: Too soft cuttings is another cause. Also, it may be important to let the cuttings dry overnight in the mist bench.

MODERATOR LEISS: What is the best way to asexually propagate *Platanus* cultivars during December and January?

JOERG LEISS: We have always made them from hardwood cuttings. If you have a greenhouse, they will be callused in 8 to 10 days.

MODERATOR LEISS: Question for John McGuire? Do juniper cuttings in April require bottom heat?

JOHN MCGUIRE: We run the temperature around 65 to 69°F, in a deep coarse sand bed with bottom heat outside.

MODERATOR LEISS: Burkwood and compact European viburnums often decay from the bottom up to the medium surface. Compact European cranberry viburnum will then often make roots in the air. Why and what can be done?

JOERG LEISS: It could be related to excess water in the medium or too high a hormone level.

MODERATOR LEISS: What is the name of the bamboo that becomes variegated in winter? How cold hardy is it?

DICK LIGHTY: It is a type of Japanese running bamboo, and it is hardy to New York City.

MODERATOR LEISS: What is the correct time of the year and method to divide bamboos?

DICK LIGHTY: In the spring before they begin growth is very effective.

MODERATOR LEISS: Question for Mark Richey. Did you change your medium from sand to perlite and, if so, why?

MARK RICHEY: It was to improve our air to water ratio. All the sand pits stopped grading their sand and it contained a higher amount of fine material.

MODERATOR LEISS: Can anyone give details on the rooting of hemlock cuttings?

HARRISON FLINT: Some time in the spring, April, proved best in a study we did in Vermont. Clonal differences are probably present.

DICK BIR: I disagree, Harrison. In our study, January was the best with April and May the worst. It picks up again in July and August. Hormodin No. 3 was as good as anything.

BRUCE BRIGGS: I think that one of you has colder temperatures and your wood is in different stages. Be sure and shade and don't let the sun burn the foliage or they will not root.

SUMMER BLOOMING AZALEAS FOR NORTHERN GARDENS

R. WAYNE MEZITT

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In the 1930's when our nursery began to expand and shift emphasis from herbaceous plants toward hardy trees and shrubs, a definite need became evident. The flowering season for most woody plants that were appropriate for our type of customers was quite short. Blossoms, with few exceptions, were limited to May and June. Those that bloomed earlier or later often lacked the garden appeal of the "in season" choices. Since we already grew a lot of our plants from seed, we decided to try to breed and select for improvements and to begin with rhododendrons and azaleas.

One of the goals in our earliest selecting and hybridizng programs at Weston Nurseries was to expand the flowering season and color choices for landscape plants. We begn primarily with early blooming species, such as *Rhododendron mucronulatum* and *R. dauricum* var. *sempervirens* and *R. carolinianum*. Results of those efforts have been gratifying and have given us incentive to continue. The rhododendron hybrids 'PJM', 'Olga Mezitt', the Shrimp Pink Hybrids, 'Weston's Pink Diamond' and 'Molly Fordham' are among those we consider successful.

The extension of the flowering time towards the later season follows a similar pattern, but with azaleas rather than rhododendrons. Our main azalea choices at the start were *R. arborescens*, *R. viscosum*, and *R. calendulaceum*. The first two are native to northeastern areas of the USA while the latter is a more southern native. We then included *R. bakeri* and *R.* ×*gandavense*, and eventually *R. prunifolium*. Surprisingly, all 6 species apparently have similar winter flower bud and plant hardiness. This good fortune enables the resulting hybrids to be useful even in many colder northern landscapes.

Although my dad, Edmund Mezitt, had performed hybrid crosses since the mid-1930's, he first began keeping records in 1950. That year he recorded 33 crosses, 8 of which were for the purpose of extending azaleas blooms later into the spring. Those first attempts involved trying to intensify flower color among naturally occurring populations of seedling *R. arborescens* azaleas. He selected for improved color and performed crosses again with them. While this did not in itself extend the season, it did create a more colorful starting point with the native species. Since *R. viscosum* was later blooming he used the same procedure with it and also began cross-hybridizing *R. arborescens* and *R. viscosum*.

One of the major breakthroughs occurred in 1957 when he received a group of plants from a collector in the Cumberland

Mountains in North Carolina labelled *R. calendulaceum*. They were June blooming in orange shades, obviously mislabeled, and later identified as *R. bakeri* [syn. *R. cumberlandense*]. His use of these plants with his now improved natives began the cycle of more colorful, fragrant and later blooming hybrids.

In about 1965, Fred Galle, then at Calloway Gardens in Georgia, sent us some plants of *R. prunifolium* he thought might be useful for extending the flowering season in our hybridizing program. His impression was that these July and August blooming southern plants might be hardier than their range indicates. My father had used *R. prunifolium* once before in his 1957 hybrids but was somewhat concerned with the potential for reduced hardiness. Fred Galle's suggestion gave my dad a renewed courage and in retrospect proved valid. Many of the seedlings from Fred Galles' plants (and dad's 1957 attempt) have tested to be flower bud hardy to as much as −24°F.

We began using *R. prunifolium* in our crosses cautiously because we could not be sure of the hardiness. Our thinking at that time was that the proven hardiness of *R. arborescens* and *R. viscosa* would probably help make some of the resulting hybrids hardy enough for northern landscapes. The same thing occured with *R. bakeri*. While we have not yet tested bud hardiness of *R. bakeri*, it performs well in our fields (USDA Zone 5) every year.

Additionally, its hybrids that have been tested demonstrate hardiness well within the range for northern gardens, often −24°F or colder.

The following will show the color progressions we've observed with various crosses and some of the influences the different parents have had.

1) 'Deep Rose'. This selection blooms in early June. It is a fragrant *R.* × *gandavense* × *R. viscosum* hybrid, tested in the winter of 1985–1986 at the University of Minnesota Landscape Arboretum and found to maintain flower viability when subjected to temperatures of —24°F. We've listed it in our catalogue since 1971.

2) 'Orange Essence'. A mid-June *R.* × *gandavense* × *R. viscosum* hybrid, this one is sweet scented and upright growing. It is still being evaluated.

3) 'Pink and Sweet'. This is an outstanding plant and one of our favorites because it is easy to propagate and succeeds almost everywhere. In 1958 we crossed a pink *R. viscosum* with *R. bakeri* and selected some superior plants. One of these was then hybridized with a pink *R. arborescens* in 1963, and 'Pink and Sweet' was one of the results. Its flower buds are hardy to −29°F and it blooms for a couple of weeks in late June. It has a strong spicy fragrance and good summer foliage that turns bronze in fall.

4) 'Lollipop'. This selection blooms in late June and is similar to 'Pink and Sweet', but a little slower growing.

5) 'Independence'. This selection is a predictable Fourth of July blooming plant with red buds, small dark pink flowers maturing silvery pink. Its scent is heavy and spicy and it has a long bloom period. Upright growing, it is probably a grex and is the result of a 1958 *R. viscosum* × *R. bakeri* cross on a dark pink *R. viscosa* in 1963. We named it in 1971.

6) 'Salute'. This selection blooms in early July with sparkling cherry-pink,

tubular flowers and a slight fragrance. It is a *R. viscosum* × *R. bakeri* parent crossed with dark pink *R. viscosum*.

7) 'Summertime'. This plant is a slightly fragrant light pink in early July. It has blue green foliage and stems, and slight mildew susceptibility. 'Summertime' is upright growing and vigorous; flowers are hardy to −29°F.

8) 'Parade'. This selection has lightly vanilla-scented, dark pink flowers for about 2 weeks in mid-July. It shows very little mildew and tests to bloom after −24°F.

9) 'Sparkler'. This outstanding hybrid has a 2 week bloom period from early to mid-July. Its dark pink flowers have ruffled edges and a spicy chocolate fragrance. The foliage is blue-green with striking silver undersides and turns dark wine-purple in fall. Flowers are hardy to −24°F.

10) 'Golden Showers'. This plant is a hybrid we've apparently named before as 'Golden Anniversary'. It blooms in mid-July with peach-yellow flowers, has a slight vanilla fragrance, and is wide growing in youth but becomes upright with age. Its origin is a 1963 *R. prunifolium* × *R. viscosum* by *R. bakeri* × *R. viscosum* cross. Its flower buds have tested hardy to −24°F. This is a beautiful plant, but it is rather susceptible to powdery mildew.

11) 'Lemon Drop'. This selection blooms from mid-to late July. It is a vigorous, stiff, upright grower. Its foliage is green with silvery undersides and turns pink-purple in fall and is mildew resistant. Flowers are pale yellow with deeper buds and lightly lemon-scented. It tests to −34°F flower bud hardiness.

12) 'July Yellow #1' is a newer selection that has a long bloom period in mid-July. Its small, rich yellow flowers have a slight fragrance. It is wide growing with good mildew resistance.

13) 'Pennsylvania' is a 1963 *R. prunifolium* × *R. viscosum* hybrid, that has light pink and slightly fragrant flowers at the end of July. Wide and slow growing, it has mildew resistant foliage that becomes coppery in fall. Even though we've grown this for a number of years, we've just begun propagating it.

The next selections tend to be even later blooming. These all have primarily *R. prunifolium* parentage and lack fragrance. All are vigorous and wide upright growing in Hopkinton, Massachusetts and have bloomed reliably for many years.

14) 'Cherry Bomb'. This plant is outstanding with its large cherry red flowers. Like the others in this group it has mildew resistant foliage. Its flower bud hardiness has tested to −24°F.

15) 'Coral Glow'. This plant is bright orange-pink and blooms from late July into August.

16) 'Tangerine Glow'. This plant is late July blooming with dark orange flowers.

17) 'Everglow'. This plant flowers from late July into August and is dark orange-red. Its foliage is somewhat glossy and its flower bud hardiness has been tested to −2°F.

Typical fall foliage variations for the *R. viscosum* and *R. aborescens* hybrids range from bronze purple to coppery orange. The *R. prunifolium* hybrids tend to remain green until foliage drop in October-November.

As you can see, we have had some good success extending color in azaleas to mid-summer. Some other significant features have also become apparent and should be mentioned for the summer blooming azaleas as a group.

1) Cold Hardiness. Quantitative testing done at the University of Minnesota Landscape Arboretum indicates extreme cold tem-

perature tolerance of flower buds in most of these hybrids. Our own qualitative tests agree. A number of other people throughout the U.S. are also currently testing them in their areas.

2) Shade Tolerance. All grow acceptably in light shade, but flower intensity and profuseness is reduced.

3) Fragrance. Flower fragrance varies from quite intense to none. It seems to be more noticable on the June to early July blooming hybrids, and also on the less intensely colored hybrids.

4) Heat Tolerance. Many of these hybrids stay in bloom, even in full sun, for upwards of two weeks with daily temperatures in the 80° and 90°F range.

5) Attractive Foliage. Foliage is most commonly green, often has some gloss or a blue or silvery underside. Many appear to be significantly mildew resistant.

6) Autumn Color. Most turn attractive colors in autumn. Mahogany-bronze tones predominate, but copper and yellow are also common. Some, including most *R. prunifolium* hybrids, have no distinctive fall color.

7) Ease of Propagation. Cuttings taken when new growth becomes stiff usually root easily. They grow more easily than many azaleas, and spring bud break is more reliable than Exbury type hybrids. Tissue culture has been successful on most we have tried.

Some of the apparent drawbacks of these summer-blooming hybrids should also be mentioned:

1) All these summer blooming azaleas are deciduous. There is nothing but stems and buds visible in winter.

2) Foliage can partially mask flower color especially on vigorously growing plants.

3) Most of the summer blooming azaleas are not spectacular garden plants in most people's minds because they bloom when everything is in full leaf.

4) They probably require acid soils to perform well, although we have not tested for pH tolerance.

5) The public has little knowledge that such plants are available, so a market will probably have to be created to distribute them.

In recent years other growers in the U.S. and overseas have also begun to offer June-blooming azaleas. Among the ones we know about are *R. "viscosephalum"*, 'Carat', 'Arpege', 'Diorama', 'Jolie Madame', and 'Rosata'. We are integrating these in our testing program and evaluating them along with our own. Some appear to have good features and we intend to incorporate them into our hybridizing program. As of this year we are tracking about 100 of our own hybrids and a couple dozen from other growers. We are currently on the fifth or sixth generation in some of our hybrids.

We see a promising future for summer blooming azaleas and a good opportunity to extend landscape color and interest to more northern gardens. We think the obvious appeal of having reliable

color at the time when people enjoy being outdoors will result in wide popularity of this type of plant. We will be continuing to hybridize and evaluate to extend color through the summer, for improved fragrance, and for optimum foliage and growth characteristics.

NEW PLANT FORUM

JACK ALEXANDER and GARY KOLLER, MODERATORS

ROB NICHOLSON:

Acer saccharum 'Globosum' is a globe-shaped sugar maple. What makes this tree of interest to the nursery trade is its small eventual size. This sugar maple has the same fine fall color as the species. We have two plants at the Arnold Arboretum. One, a 45 year old plant, is about 25 ft high by 18 ft wide and was grafted low to the ground. It could also be grafted as a standard. I don't know about the history of this cultivar but we received our material in 1942 from the Henry Hohman Nursery in Kingsville, MD. I see this cultivar as an excellent tree for lawn, patio or park use.

Betula grossa, the Japanese cherry birch, is a small tree that has shown no pest problems at our arboretum. It is native only to Japan and is found in the lower three islands but seems to be most common in the central provinces of the large island, Honshu. Its bark, while not being a "commercial white", is a fine silvery-maroon color which resembles the bark of some cherries. It is reported to reach over 50 ft in Japan but in Boston our trees have not topped 30 ft One of our trees is 90 yr old and only 30 ft high. A 30 yr old plant grown from seed is 25 to 30 ft high and shows a nice pyramidal habit. The hardiness of this birch is probably Zone 5.

GARY KOLLER:

Heptacodium of the Caprifoliaceae is a new genus of shrubs, first arriving in North America as a result of the 1980 Sino-American plant collecting expedition of which the Arnold Arboretum was a cooperating institution. *Heptacodium jasminoides* grows 20 to 22 ft tall and forms a large shrub or small tree. The most distinctive ornamental feature is the small, white, fragrant flowers produced from mid-August to early October. Blossoms are followed by rose-purple fruits borne in large terminal clusters which are especially showy when backlit by late afternoon sun. Propagation is easy from softwood cuttings. Growth is 2 to 3 ft or more per year and flowering occurs the second growing season. A full account on the introduction, ornamental features and growth of *Heptacodium jasminoides* can be found in *Arnoldia*. 1986. 46 (4):2–14.

ALAN GORKIN:

The plant I will present here is not new. *Cercis chinensis* was introduced to this country from China in the late 1800's. While it may be grown in the southern portion of the U.S., especially the southeast, one rarely encounters it in the mid-Atlantic to northeast areas. The Chinese redbud is hardy to Zone 5 USDA, (Zone 6, Arnold). *Cercis canadensis* is hardier than *C. chinensis*. *Cercis chinensis* is a multistemmed small tree or large shrub to 12 ft. Redbuds do best on well drained soils and transplant best in spring. They grow well with a pH in the slightly acidic range (6.0 to 6.8). Flowers occur up and down stems in early spring before leaves develop. Leaves are attractive, thick, dark-green, leathery and heart-shaped appendages. The only possible drawback is its retention of seed pods into the winter. Some have germinated fresh

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seed collected before the seed coat is fully developed and seed coat dormancy established. Timing is fairly critical since the seed must be mature. Seeds have impermeable coats and must be scarified before receiving moist stratification. It does well in the shrub border, foundation planting or possibly as a street tree or shrub if pruned.

CHRISTOPHER ROGERS:

Rhododendron 'April Snow' is a lepidote whose parentage goes back to the 1940's. Two of its parents are a semi-double 'PJM' and a white *R. dauricum* var. *sempervirens*. It blooms in mid-April and has fully double pure white flowers. It is a vigorous grower, with a wide upright growth habit. Foliage is light green and persists throughout the winter. Flower buds have tested hardy to −18°F.

Rhododendron 'Olga Mezitt' is a cross between a chance seedling of a pink semievergreen azalea (*R. mucronulatum*) crossed to a *R. minus* "compactum", which was received from Wayman's Framin ham Nursery in the late 1950's. It blooms around Mother's Day with clear pink flowers. The shiny and reflexed leaves change from bright green in the summer to dark mahogany in the winter. Flower buds have tested hardy to −24°F.

Rhododendron 'Aglo' is a sister of 'Olga Mezitt'. It blooms two days earlier than 'Olga Mezitt' with light pink flowers containing a darker center. The leaves are similar to 'Olga Mezitt' but change to a bronze-mahogany in the winter. Flower buds have tested hardy to —24°F. The original plant is more spreading than its sister 'Olga Mezitt'.

WILLET WANDELL:

Amelanchier × *grandiflora* 'Autumn Brilliance' is a vigorous growing, small tree to 18 ft. 'Autumn Brilliance' is a heavy bloomer and has brilliant red fall color in October. It is resistant to summer leaf drop caused by *Entomosporium maculatum*.

MICHAEL KACZOROWSKI:

Rhodotypos scandens, jetbead, is not an unusual rare or glamorous plant; that's why I think it is a valuable plant in the landscape. It has 4 assets that endear it to me. 1) It is a good transition plant where the formal landscape ends and a naturalizing plant is needed. It has a mounding habit with branches that ascend and then arch. 2) It grows equally well in full sun or heavy shade. 3) Its functional size, 3 to 4 ft. high and 4 to 9 ft. wide, makes it very flexible. In deep shade both height and spread fall into the lower range. 4) It has no serious insect or disease problems. Jetbead roots easily from softwood cuttings taken in the spring. Seed requires both acid scarification and cold treatment. Jetbead grows best in Zones 4 through 8. It flowers in May and early June. The flower is 4-petaled which is unusual for the Rosaceae. The summer foliage is clean, medium to bright green in color and the 3 to 4 shiny black fruits persist into the spring.

SIDNEY WAXMAN:

Pinus strobus 'Paul Waxman' was selected from a population of seedlings obtained from a witches'-broom in 1963. This dwarf specimen is unusual because it is more than twice as broad as tall. This low-growing broad mound is densely branched and has a fine texture. It measured, after 22 years from seed, 4¾ ft across and only 2 ft high. Its annual growth rate in width is approximately 2 in. Its needles are slightly curved and very short; measuring only ⅞ in. in length. The foliage exhibits two color tones, a mixture of green and blue-green. This two-tone effect has been observed on this selection as well as on several other plants of the same progeny and is the result of the partial opening of the needle bundles or fascicles. The green color is exhibited near the base of the fascicles where the fine needles have separated exposing the stomatal coloration.

Tsuga canadensis 'Howard Waxman' was a graft taken directly from a witches'-broom found in Storrs, Connecticut. It is a very compact hemlock with rigid branches that curve down. The foliage is extremely dark green and very dense. This selection does not exhibit the bleaching of the upper foliage that is common on many dwarf, dense hemlocks. 'Howard Waxman' is twice as wide as high. Its dimensions, 11 yr

after having been grafted, is 3¾ ft wide and 2 ft high. It's annual growth rate is approximately 4 in.

Sciadopitys verticillata 'Joe Kozey' was selected from among many seedlings grown at the University of Connecticut nursery. This seedling differed from the others because of its form. Unlike most unbrella pines which tend to produce many vigorous terminals that compete with one another, this selection has a strong leader that remains dominant. As a consequence it develops into a taller and more conical tree than the typical unbrella pine. It has grown to a height of 6 ft after 10 yrs. from a rooted cutting and has an annual growth rate of approximately 10 in. Its foliage is dark green and during the winter months turns slightly bronze on its western exposure. Our nursery is located on the crest of a hill with full exposure to sun and wind. Under a more protected environment this tree retains good winter color.

It can be rooted from cuttings quite readily. Cuttings taken from 10-year-old plants rooted 80%.

RICHARD MUNSON:

The Chinese neillia, *Neillia sinensis,* is a deciduous shrub in the rose family, 3 to 6 ft in height with an equal spread, noted primarily for its light pink flowers produced in pendulous terminal clusters. The flower racemes, which contain 10 to 20 bell-shaped flowers, are produced in late May in western Massachusetts. Leaves are alternate, simple, and toothed, with a bright crisp-green color. Because the branches are spreading and somewhat pendulous, the plant is less vulnerable to breakage from ice and snow. Chinese neillia is particularly well-suited to bank plantings and other sites where its graceful branching habit can be accentuated. A native of China, the plant is listed by some references as being hardy to USDA Hardiness Zone 4 while other sources list it as being hardy to Zones 5 to 7. It performs well in the Zone 5 to 6 borderline area and has suffered no appreciable damage during unseasonable cold periods. Although the fall color is a rather unspectacular dull yellow, the winter character is attractive because of the pendulous light to medium brown branches with exfoliating bark.

Chinese neillia is propagated by several means. Softwood cuttings may be rooted under mist or plastic. Hardwood cuttings can be callused during winter for spring rooting. One source lists propagation by seed, but does not provide details. Presumably the seeds should germinate after a moist-chilling period of approximately 90 days.

BOB CARLSON:

As a grower and propagator of more than 1200 cultivars and species of azaleas and rhododendrons, I'm here to suggest that, while we probably are growing too many at Carlson's Gardens, most nurseries are offering too few. Consider the white azaleas that are most commonly found in garden centers. 'Delaware Valley White' is a glaring, chalk white that can hardly be said to blend easily in an informal azalea garden. But at least it is lower growing and has a less upright growth habit than 'Polar Bear', which is the other chalk white too frequently offered.

Much more subtle in their coloring is a new group of *R. mucronatum* hybrids that we have started offering to our retail mailorder customers. We call them "Carlson's Face 'em Down Azaleas" because of the pleasing landscape effect they give when planted in front of taller, leggier shrubs. We find that a planting that includes several different clones is much more interesting in bloom than if only one clone has been used. Yet because their foliage and plant habits are so similar, they can give the massing effect that designers call for the other 56 weeks of the year. 'In The Pink' is white with tints of lavender pink. Like most of this group, close up it gives the effect of a water color wash, while from a distance it carries as a soft white. The second clone is called 'Foamy'. I should also point out that in addition to having a pleasing fragrance, these plants have been growing for the past 15 yr in USDA Zone 6a without any form of winter protection. The original plant is approximately 4 ft in diameter by 2 ft high in 15 yr.

CONNOR SHAW:

New Jersey tea, *Ceanothus americanus,* has many horticultural traits that should induce nurseries to grow it. It ranges as far north as southern Manitoba, south to Florida, and west to Texas. The plant is hardy to Zone 2. This *Ceanothus* grows to a height of about 2 meter (3 ft) and therefore makes an excellent plant for placing in front of taller shrubs. New Jersey tea has white flowers the first two weeks in July in the Chicago area. Few other shrubs bloom at this time. It is adaptable to very droughty sites and also does well on heavy clay soils. Ceanothus fixes its own nitrogen which is unusual for a non-legume.

New Jersey tea has folklore. The plant was used as a substitute for tea during the revolutionary war and the tea is very good being similar to the green tea of China. The root was used for a red dye.

Propagation of New Jersey tea is very easy once you have the seed. We collect the seedheads as soon as they turn brown and place them in a plastic bag in the greenhouse. Seed is forcibly ejected from the seedheads. One week later the seed is separated from the heads and put into a jar and stored in a cool room. The seed needs scarification. The seed is placed in boiling water, the heat is turned off, and the seed is allowed to sit in the water overnight. The next day the seed is placed in flats with bottom heat. Once the seedlings are big enough to transplant they are placed in bottomless containers. The plants next go to the field in August or the following spring depending on field conditions.

DENNIS BRUCKEL:

Daphne × *burkwoodii* 'Carol Mackie' originated in 1962 as a variegated sport of *D.* × *burkwoodii* 'Somerset'. The subtle variegated pattern on the leaf margins makes this plant attractive and salable at any season. Fragrant pink flowers open in early June in Vermont, and fade to nearly white, 'Carol Mackie' grows 3 to 4 ft tall with a similar width. The plant survives winter temperatures of −30°F without injury. While essentially evergreen in sheltered locations, excessive winter wind and sun will result in considerable leaf drop during winter.

Propagation procedures at Grand Isle Nursery are based on very softwood cuttings taken in June through August. For suitably soft late summer cuttings, it is essential that stock plants be heavily pruned 2 to 3 weeks prior to cutting collection. We treat with Hormodin #3, stick in 1:1 vermiculite and perlite and root under mist. Presently we pot rooted cuttings in 4 in. square pots for about 30 days prior to outplanting in Vapam-treated transplant beds. We get vigorous growth late that season, and cover with microfoam during winter to prevent frost heaving. The following season we use this bedded stock to supply cuttings, giving us a well-branched, 9 to 12 in. plant in late summer for canning or lining out for future B&B material.

JACK ALEXANDER:

Elsholtzia stauntonii, the mint bush, is native to northern China. Known to botanists for some time, it was not introduced into cultivation in the U.S. until 1905 when J. G. Jack of the Arnold Arboretum brought back cuttings on his return from China. As in many other members of the mint family, the Labiatae, its leaves, stems and floral parts emit a characteristic mint odor when bruised. The rosy or purplish pink flowers produced in mid-September in the Boston area when few other shrubs are in bloom, are its most important ornamental feature. There is also a form with white flowers. The flowers are produced in terminal and axillary panicles. Terminal panicles are usually 5 to 7 in. long while the axillary panicles are 3 to 4 in. I have, however, measured panicles that were 9 in. in length.

Mint bush is considered to be hardy to −20°F, but since it produces its flowers on new growth, winter injury from colder temperatures can be pruned out without seriously affecting the early fall floral display. Some authors even suggest that this shrub be routinely pruned back to 1 to 2 ft after flowering. Such severe pruning suggests that this plant be grown almost as if it were an herbaceous perennial and I believe that it might serve very well in just such a capacity. It will tolerate poor soils, but does best in a good garden loam and full sun. It can be propagated from soft-

wood, greenwood, and hardwood cuttings and from seed, which exhibits no dormacy.

RICHARD HESSELEIN:

Hydrangea quercifolia 'Snow Queen' (Plant Patent No. 4458) is a cultivar of the native oakleaf hydrangea. It is notable for the large size and pure white color of its flowers. The parent shrub, which was discovered on the Princeton Nurseries, has many more sterile flowers in the flower panicles than is the case with the species. This means that the panicles are much fuller looking and more decorative. They are a clear snow white color when they open in early July and gradually turn pink as they mature in August. Unlike the fully sterile forms of this species, the panicles are held erect on stiff stems even after heavy summer rains, when the flowers of sterile plants droop down and become hidden in the foliage. 'Snow Queen' grows to a height of 5 or 6 ft and is winter hardy in Zone 5. It is one of the few deciduous shrubs which grow well in the shade as well as full sun. The bold, handsome foliage which resembles oak leaves, is a dark green color in the summer and turns a beautiful red-purple color in the fall. The peeling bark of the stems and orange buds are attractive in the winter months. It is an ideal shrub for combination planting with conifers and broadleaf evergreens.

With the growth in popularity of sophoras for street planting, there has been a need for a more upright growing form to give ample clearance for pedestrian and vehicular traffic. The Princeton upright pagoda tree (*Sophora Japonica* 'Princeton Upright,' Plant Patent No. 5524) was selected from a block of seedling sophora trees growing on Princeton Nurseries. It is a vigorous grower with attractive shiny foliage and a distinctly upright branching pattern. The crown broadens with age, but maintains a high head of branches with the twigs held well above the horizontal level. It bears compact globular heads of pea shaped white flowers with a yellow flush in the center of each blossom. It flowers for a long period in mid-summer from late July to late August when very few other trees are in bloom. 'Princeton Upright' is highly resistant to the twig die back which many sophoras of seedling origin exhibit. It is also resistant to the bark canker which troubles the species in areas with a humid climate. Like all sophoras it is particularly resistant to high temperatures, polluted atmosphere, and heat reflected from pavement and building walls in city locations. It tolerates drought and high pH soils which will turn oaks and many maple species yellow.

ELWIN ORTON:

Rhus chinensis 'September Beauty' is the most recent introduction from the woody ornamentals breeding program at Cook College, Rutgers University—The State University of New Jersey. It is the first named cultivar of this species and is being introduced as our field tests indicate that it is an excellent clone.

A typical plant of 'September Beauty' is a multi-trunked, small to medium sized, spreading tree with a mature height of 20 to 30 ft. Plants of this cultivar rapidly develop as trees since 4 to 6 ft of growth per year is not uncommon when the plants are young. The trees are surprisingly strong-wooded for plants that exhibit such rapid growth.

The creamy-white flowers are borne on compound panicles which average 18 to 22 in. in length and 15 to 20 in. in width. These large inflorescences, as well as the tiny flowers, provide an attractive floral display from late August through mid-September in central New Jersey (USDA Plant Hardiness Map Zone 6a). The plants are staminate so there are no fruit to pose a litter problem as might be the case with a pistillate selection.

The leaves are pinnately compound and exhibit an excellent dark green, glossy appearance. Some years, the foliage provides a brilliant display of fall color, but this characteristic is variable from year to year.

Plants of 'September Beauty' are readily propagated from root cuttings. In late winter, direct-stick a 3-in. rootpiece vertically in a one- or two-gallon container with the proximal end of the cutting even with the surface of the growing medium. Callus will form at the cut surface and several adventitious shoots will emerge at that point. Rub off all shoots except the best one.