Oregon's Horticultural Success Story: the Hazelnut©

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I want to thank Verl Holden and Gayle Suttle for the invitation to visit with you this morning. I am deeply honored to be a part of your program. Including the topic of hazelnut production while in Oregon was brilliant!

HAZELNUT PRODUCTION – A WORLD PERSPECTIVE

Hazelnuts (*Corylus avellana*) survive in many varied climatic and soil conditions; however, to consistently yield enough for a commercial crop they require more suitable conditions. The soil must be good quality and although hazelnuts love rain, the soil must be well-drained as they are not fond of wet feet. The climate must be mild without long periods of extreme cold or extreme heat. It appears that the 45th parallel provides excellent conditions. In the Northern Hemisphere the current production areas include the Black Sea region in Turkey, Georgia, Azerbaijan, Italy, Spain, and Oregon. In the Southern Hemisphere hazelnuts are being cultivated in Chile, South Africa and Australia.

Turkey is the largest producer of hazelnuts by far with about 70% of world production. Oregon produces from 3 to 5% of the world's supply. In Turkey the cultivars grown are smaller in stature, bearing smaller nuts that are more conducive for use as kernels than as inshell. Trees are grown as bushes that grow on the sometimes steep hillsides along the Black Sea. There are thousands of growers that have 1 or 2 ha of hazelnuts planted. The hazelnuts are harvested by hand and spread out to dry in the sun. When dried and husked they are transported to very large modern processing facilities where most are shelled, further processed and shipped throughout the world. Notably, the dependency on the weather for the drying process can be disastrous for the industry. Timely drying is imperative for top quality product.

THE OREGON HAZELNUT INDUSTRY

The Oregon industry is comprised of about 650 growers, many multigenerational. The average-size orchard is 50 acres. Horticulturally, as you are likely already aware, the hazelnut tree is quite amazing. In Oregon, growers culture the trees to grow with a single or multiple truck system, but suckers are controlled so trees do not become bushes. While other trees are dormant during the winter months, the hazelnut trees are busy propagating. The catkins elongate in December and a wondrous yellow appears among the bare tree limbs. Wind and rain disperse the pollen to the tiny red flowers which can barely be seen. Later in the spring fertilization occurs and by mid-summer there are signs of tiny nuts forming.

As the summer progresses the nuts become more prominent and by late-summer they begin to take on the "hazel" color. When fully mature the nuts fall free of their husks to a carefully managed clean orchard floor. Growers mechanically harvest their crop by sweeping nuts into windrows and then picking them up with a harvester. The harvester is designed to eliminate sticks and leaves and the nuts are conveyed into totes or in bulk trailers. They are immediately transported to handlers who wash and dry them as quickly as possible. This helps ensure the quality of Oregon hazelnuts. After drying the nuts are sized and sold either in the shell or cracked and further processed. All Oregon hazelnuts are graded for size and quality by the U.S.D.A. before being put into any channel of trade.

During 2012 the crop totaled 37,000 short tons. Sixty-nine percent of the crop was exported in the shell. The rest was either shelled or sold domestically in the shell. A large majority of the exports went to China where most are slightly cracked, soaked in a brine solution and roasted. They are consumed as snack nuts.

Here in the U.S. most hazelnuts are sold as ingredients. They are found in a range of foods including health bars, yogurt, spice blends, ice creams, snack mixes and, of course, with their favorite partner, chocolate. Portland is known for its breweries and several hazelnut beers as well as hazelnut rum.

THE OREGON HAZELNUT GROWERS

The individuals who grow hazelnuts in Oregon are a hardy lot. They are forward thinkers and anxious to share their successes and failures with their fellow growers. The Oregon hazelnut industry would not exist today were it not for their decision to partner with Oregon State University (O.S.U.) to figure out how to overcome eastern filbert blight (EFB), which reared its head about 30 years ago. Growers attacked this disease that was responsible for the demise of the industry on the East coast via a two-pronged approach. Long-term, they engaged the O.S.U. breeding program, specifically, hazelnut breeder Dr. Shawn Mehlenbacher to add EFB resistance to the traits for which he was selecting. Support from the industry and other sources enabled Shawn to travel the world to identify potential EFB resistant parents for the program. Short-term, growers engaged the OSU plant pathology department to learn more about the disease and create methods to keep trees alive long enough for the breeding program to release completely resistant cultivars.

The results are quite graphic in this history of hazelnut production over the last 17 years. The acreage over this time and immediately prior to this was pretty constant at about 28,000 acres. Very few growers even considered planting additional acreage when the trees they were to plant would definitely become blighted. Hazelnuts are alternate bearing, so there were obvious on and off years. But, if you look at the trend, it was clear that all the efforts to figure out how to manage the disease were ultimately beneficial to the industry. Precision pruning, protective spraying, ensuring proper nutrition for the tree at the most beneficial times of the year; all these practices and others were paramount in keeping EFB infected trees in production. The industry also instituted a control order so that trees from the infected area could not be transported to the uninfected area.

In the late nineties Dr. Mehlenbacher released ‘Lewis’, ‘Clark’, and ‘Sacagawea’, each with quantitative resistance to EFB. Growers started thinking about the more resistant cultivars that were on the horizon. Soon the growers began to plan for the release of completely resistant cultivars. They put resources into researching how to micropropagate the hazelnut (Fig. 1).

Fig. 1. A young plantlet coming out of micropropagation.

Prior to this it was felt there were issues that made micropropagation impractical. Some of the micropropagators in the audience today were willing to meet with the industry and discuss their thoughts on micropropagating a crop that would stay in the ground over 100 years...translation...may NOT make them a lot of money over time. With contributions of knowledge from all sectors, the mechanics of hazelnut micropropagation were developed and an additional avenue for growing new cultivars in large numbers was born.

'Jefferson', 'Yamhill', 'Dorris', 'York', 'Felix', and 'Wepster' were released along with other compatible pollinizers. Each release provided opportunity for growers to begin to pull out their infected trees and plant with new resistant cultivars. Concurrently, the price stayed pretty stable and the industry attracted the attention of some farmers of other crops. While statistics are not complete at this time, it appears that, very conservatively, there has been an increase of 3,000 new acres planted each year beginning in 2009.

The push for EFB resistant cultivars with high-quality characteristics has not slowed. Dr. Mehlenbacher and his colleagues are now looking at various sources of resistance and the layering of resistant genes to ensure cultivars that will stay healthy over time. The micropropagators are serving an increasingly important role as more cultivars are released and the demand increases.

I would like to extend a special thank you to the members of the team of hazelnut plant breeders at O.S.U., the propagators and the members of related disciplines such as plant pathology and extension, who have created a "light at the end of the EFB dark tunnel" and have provided inspiration for growers to continue to plant and for new growers to begin to plant hazelnuts in Oregon and Washington.

MORE HAZELNUTS MEAN MORE MARKETS

Skeptics have looked at this growth and indicated it may be difficult to sell more Oregon hazelnuts. While Oregon has traditionally not had a problem with selling hazelnuts, an expansion of the industry at this point in history provides incentive to marketers to tap young markets. It is an excellent time for this. The industry has yet to reach the critical mass necessary to be of interest to those large brand name buyers right here in the USA. With new acreage, this will be possible. In addition, there are other markets around the world as yet untapped.

The importance of tree nuts for health cannot be underestimated. The hazelnut provides not only the health benefit but also an amazing flavor and crunchy texture that make it a premium nut. The hazelnut is part of the group of tree nuts that sport an FDA qualified health claim for heart health. The nutrient profile of the hazelnut includes Vitamin E, folate, minerals, and phytonutrients each providing unique health benefits.

To summarize then, thanks to long term thinking multigenerational growers, plant breeders, propagators in this room, and the inherent qualities of the species; if you are looking for that silver bullet food, hazelnuts, packed in their own protective shell, may just be the closest you will find. We call them "Indulgence in a Nutshell."

They are easy to incorporate into any dish. Unlike some foods, they are not very perishable. Unlike wine you can eat them and drive. And, they are sustainable — they have been around for over 4,500 years. When you are done cracking them, just throw the shells in your nearest planter or flower bed — they make amazing mulch.

Harvest is upon us and the holiday season is approaching. Maybe you will add hazelnuts to your own culinary creations. When you do, perhaps you will feel the "smiles" from the large team of folks who have made Oregon hazelnuts possible. Thank you so much.

QUESTIONS AND ANSWERS

Richard Criley: Why the name hazelnut instead of filbert?

Polly Owen: They were all called filberts until we started exporting them. Many people around the world didn't recognize that name so we went to "hazelnut."

Richard Criley: What constitutes "quality" in a hazelnut?

Polly Owen: Quality measures include size, flavor, and crunchiness. The relative importance of these three characteristics can change depending on how the nut is used.

Scott Ekstrom: How and when are hazelnuts picked?

Polly Owen: For more than 100 years there have been two main cultivars, ‘Barcelona’ and ‘Ennis’, but with the newer cultivars that are resistant to eastern filbert blight we have a huge transition going on. For the most part they were sold as “in-shell” and the kernels were the by-product. What we’re beginning to transition to is an era where you will be marketing 5-year cultivars and with a mix of kernel cultivars with in-shell cultivars. A more important consideration is getting the proper cultivars planted together for cross-pollination and maximum yields. Compatible cultivars in terms of yield, bloom time and pollen shed must be planted together.

Nursery Certification©

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Preventing, or at least slowing down, the spread of invasive alien species has become a difficult challenge for government agencies worldwide. Between 1996 and 1999, North America, including Canada, the United States, and Mexico, were invaded by six major alien species that were and still are serious pests of plant crops. By 2010 the number of alien pest species that have inadvertently been introduced into North America has more than quadrupled. Three of these alien pest species are serious pests of nursery crops: sudden oak death (*Phytophthora ramorum*), Asian long horn beetle (*Anoplophora glabripennis*), and emerald ash borer (*Agrilus planipennis*).

The North American Plant Protection Organization conducted an analysis of the pest introduction data. The research concluded that the following factors have resulted in ineffective prevention of stopping the introduction of serious pest species.

1) Regulatory agencies tend to rely on historically based pest lists and miss the possibility of other introductions.
2) Infested plant material (or wood products) can be a source of infection indefinitely (quarantine periods may not be effective).
3) Pest detection by government officials can occur long after the pest has been established.

Pest risk analyses for imported plant material are researched by regulatory agencies to establish directives for importing new plant species introductions or importing plant species from a different country source. A pest risk analysis designation resulting from an import request may have a high degree of uncertainty because the importer is uncertain of the true origin of the plant material (geographical area where the species was first discovered) and/or is uncertain of the propagation mother stock source. Coupled with this lack of accurate source information is the fact that many plants are shipped through a number of plant suppliers before arriving at the final North American destination. Further, there is still limited or no scientific information about some alien pest species. In particular, disease pathogens are often not as well understood as arthropod pest species life cycles.

Despite regulatory inspections, quarantines and import restrictions, several pest species have been introduced into North America on nursery stock imports. Examples are citrus long horn beetle (*Anaplophora cinnensis*) found on Korean bonsai and brown rot (*Ralstonia solanacearum* Biovar 2) that was imported on infected geranium cuttings from Kenya, Guatemala, and Costa Rica. Nursery stock imports are the chief suspect in the introduction of sudden oak death (*P. ramorum*) to the western United States of America.

There are several options to the present North American regulatory regimes. One option is to continue with the status quo. Unfortunately, that will mean a continued introduction of potentially detrimental alien pest species despite border inspection efforts. Border inspections could increase in number and intensity, but there is limited government funding and symptoms of these pests are often not observable when plants are inspected. Pre-clearance at source has the same limitations as inspection at arrival. Because of these limitations, Canada, the United States, and Mexico have implemented or are currently studying certification programs that are clean-stock-systems approaches to reduce the introduction and spread of alien pest species. There are international guidelines for certification on which domestic programs can be built. The main advantage of certification is that continuous year-round efforts of pest detection and control are much more effective at the nursery rather than relying solely on a pre-shipping inspection. However, there are significant disadvantages especially for nursery owners. Costs can be high for both staff training and maintenance of the program. These costs must be included in the cost of production which may or may not be redeemed. Federal government agencies may have to offer significant incentives to establish effective certification programs. As well, certification programs require audits or an oversight mechanism to satisfy the needs of the importing country. Despite these disadvantages both the North American Plant Protection Organization (NAPPO) and the International Plant Protection Convention (IPPC) view certification as the way of the future for the international movement of plants and plant parts.

An effective certification program is based on a systems approach. Two or more measures or procedures that are independent of each other are required to manage risk of introduction or spread of a regulated pest. The program can also include a number of measures or procedures that are dependent on each other. All procedures must be written in a manual. When a procedure is carried out (e.g., inspection at receiving) there must be a record. This could be a simple stamp with the inspector's initials on a shipping document (packing slip). Audits check that all certification program procedures are carried out routinely and accurately.

Examples of the British Columbia *P. ramorum* (sudden oak death) Certification Program procedures or measures are listed in the table below.

Table 1. British Columbia *Phytophthora ramorum* (sudden oak death) Certification Program procedures or measures.

Independent measures/procedures	Record keeping
Certified *P. ramorum* by suppliers or, free of symptoms by government agency	Copy of Phytosanitary Certificate or nursery certification number
Visual inspection upon arrival	Copy of packing slip signed of as inspected
Test leaf spots with field test kit – (assume negative)	Signed paper in file showing negative test
Plants placed in isolated bed	Record of which bed and when placed
Regular visual inspection for leaf lesions during production period	Copy of these inspections in the file
Spray with Subdue Max	Copy of spray records in file

There are several factors that contribute to an effective certification program. Proper training of managers and staff is a key component. Many hours can be wasted trying to implement measures or procedures that are ineffective or too time-consuming to be useful. Once effective and efficient procedures have been identified and recorded, staff must be given access to the materials and time to carry out these procedures. Otherwise, they will not be done routinely or effectively. Therefore, managers must clearly delegate responsibility for each procedure to individual staff member. Management must follow up to ensure that the program procedures are always in place.

Record keeping is a major tool in an effective certification program. Records are used for both internal audits that are carried out by company employees and external audits that are conducted by independent auditors. The audits will verify that the procedures are in place and are effective. Certification programs currently in place for trans-border shipment of plants include greenhouse certification programs and nursery certification programs. A voluntary program in Canada, Clean Plant Program, has replaced the *P. ramorum* Certification Program.

QUESTIONS AND ANSWERS

Todd Jones: Does this joint program between Canada and the USA standardize the testing and permitting?

Carol Barnett: Yes, I believe so.

Todd Jones: Is it in place yet?

Carol Barnett: No.

Mark Krautmann: I'd like to thank the program committee for having you here, Carol. Professionalism calls us to a high standard in this regard. If we're going to aspire to hold and expand our markets we must set and maintain the highest standards we can achieve.

Carol Barnett: Propagators have a large commitment to this effort since we start the process.

The PlantRight PRE: a New Screening Process for Invasiveness©

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INTRODUCTION

Sustainable Conservation's initiative to stop the sale of invasive ornamental plants in California's horticultural industry, PlantRight, is introducing its Plant Risk Evaluation (PRE) tool to commercial leaders in the horticultural industry. We are working to promote adoption by the industry and have launched a pilot project with a handful of leading growers and propagators who introduce new horticultural plants to determine how our tool can fit into their new plant development process. We developed the PRE tool, which has a 98% accuracy rate in predicting invasive plant characteristics, in collaboration with University of California, Davis (U.C. Davis) and the University of Washington to screen plants with the long-term goal of industry wide adoption to prevent the introduction of new ornamental invasive plants in the nursery supply chain.

Screening new ornamental plants to determine the risk of invasiveness is the most cost-effective way to prevent the introduction of invasive plants (Leung et al., 2001; NISC, 2001). The PRE tool estimates the risk of an ornamental plant species becoming invasive in a defined geographic or climatic region, which can help a company determine not only where a given plant species (or subspecies) poses a potential invasive risk, but also where it does not represent an invasive risk and could potentially be grown and sold. Invasive ornamental plants represent both a risk and an opportunity for the nursery industry, particularly for plant propagators and companies that develop new plant material. Since companies make a significant financial investment in developing new plant material, predictive tools like the PRE are a cost-effective way to determine risk of invasiveness early in the research and development phase, avoiding USDA-APHIS quarantine restrictions (Q37) (Koop et al., 2010), and preventing the unintended negative economic and ecological consequences of new invasive plants. Despite the large number of new ornamental plants introduced by the industry, less than 1% have become invasive (Gordan and Gantz, 2008). We expect a low percentage of new ornamental plants would screen as invasive with the PRE tool.

The PRE provides other valuable information about plant species for propagators including detailed information on taxonomy, patent information, history (culinary and medicinal uses, toxicity, etc.), regional climatic suitability, plant demographics (growth, reproduction, and dispersal), and ecological characteristics that provide insight into a plant's suitability as an ornamental (pests and disease problems, aggressiveness, changes soil chemistry, fire hazard, etc.).

MATERIALS AND METHODS

Six industry leaders participated in our pilot project (Ball Horticultural, Blooms of Bressingham, EuroAmerican Propagators, Hines Horticulture, L.E. Cooke, and Quarryhill Botanical Garden) by supplying a list of plant names of their choice to screen with the PRE tool. They did not disclose why they chose those species or what they expected the results to be. All species were screened with the PRE tool between July and Sept. 2013. We will meet with each company individually to review their PRE results, gather their feedback on the findings, and discuss what value the PRE tool has for their company.

The PRE tool, developed by Dr. Lizbeth Seebacher (University of Washington), calculates a score associated with the risk of a plant species becoming invasive in a defined region by answering 29 weighted Yes/No questions about life history, biogeography, biology, and ecology (Pheloung et al., 1999). To answer the questions, a complete literature review is conducted using peer-reviewed literature, online and plant taxonomic and invasive species databases, books, and government and Non-Governmental Organization (NGO) factsheets. Questions that cannot be answered due to lack of available information are answered "unknown". Plants with a score >18 are rejected (high risk of invasiveness), 15 to 18 require "further evaluation", and <15 are accepted (low risk of invasiveness). The "evaluate further" score requires additional assessment by an expert panel. The PRE is conducted by trained graduate students from U.C. Davis Department of Plant Sciences.

RESULTS/DISCUSSION

Of the 49 perennial plant species screened with the PRE (Table 1), the majority (80%) were accepted (low risk of invasiveness), while only 6% were rejected (high risk of invasiveness), and 14% were classified as "Evaluate Further" (Fig. 1).

We also evaluated which questions in the PRE tool were most predictive of invasiveness (Fig. 2). Ninety-eight percent of the plant species that scored as invasive were also found to be invasive in other parts of the world or were members of a genus with other invasive species, while less than half of the species that screened as non-invasive shared those characteristics. Similarly, a much higher percentage of species that scored as invasive had highly aggressive growth and reproductive characteristics.

Table 1. Plant species screened with PlantRight PRE for pilot project.

Scientific name	Common name
Herbaceaous forbs	
Anemone hupehensis 'Pretty Lady Diana'	windflower
Anemone hupehensis 'Pretty Lady Emily'	windflower
Anemone hupehensis 'Pretty Lady Julia'	windflower
Anemone hupehensis 'Pretty Lady Susan'	windflower
Argylia radiata	argylia
Aster ageratoides	chosen-nokongiku
Campanula poscharskyana 'Blue Rivulet'	bellflower
Campanula poscharskyana 'Blue Waterfall'	bellflower
Coreopsis rosea 'Sweet Dreams'	tickseed
Coreopsis verticillata 'Golden Dream'	tickseed
Coreopsis verticillata 'Sweet Marmalade'	tickseed
Cynoglossum amabile	Chinese forget-me-not
Echinacea purpurea 'Supreme Cantaloupe'	coneflower
Echinacea purpurea 'Supreme Elegance'	coneflower
Echinacea purpurea 'Supreme Flamingo'	coneflower
Euphorbia polychroma 'Bonfire'	spurge
Geranium 'Azure Rush'	cranesbill
Geranium 'Gerwat', Rozanne™ cranesbill	cranesbill
Gloxinia sylvatica	gloxinia
Helianthemum 'Hartswood Ruby'	sun rose
Helichrysum amorginum 'Blorub', Ruby Cluster™ everlasting	strawflower

Table 1. Continued.

Scientific name	Common name
Heliopsis helianthoides var. *scabra* 'Bressingham Doubloon'	ox-eye sunflower
Heliopsis helianthoides 'Helhan', Loraine Sunshine™ ox-eye sunflower	ox-eye sunflower
Houttuynia cordata	chameleon plant
Hypericum olympicum	Mt. Olympus St. John's wort
Leucanthemum × superbum 'Engelina'	shasta daisy
Leucanthemum × superbum 'Freak!'	shasta daisy
Lithodora diffusa 'White Star'	lithodora
Nelumbo nucifera	East Indian lotus
Penstemon × mexicanus 'Sweet Joanne'	beard tongue
Perilla frutescens	mint perilla
Sedum kamtschaticum (syn. *Phedimus kamtschaticus*)	orange stone crop
Thalictrum delavayi	chinese meadow rue
Grasses	
Chondropetalum tectorum	cape rush
Cyperus luzulae	deeprooted sedge
Deschampsia cespitosa	tufted hair grass
Juncus thomsonii	zhan bao deng xin cao
Pennisetum purpureum 'Vertigo'	pearl millet
Shrubs	
Buddleja nivea	nivea butterfly bush
Calceolaria integrifolia	bush slipperwort
Cytisus × spachianus	sweet broom
Elaeagnus umbellata	autumn olive
Salvia canariensis	canary island sage
Senna didymobotrya	peanut butter cassia
Solanum pinnatum	no common name
Trees	
Acer davidii	David's maple
Cornus macrophylla	large-leaf dogwood
Elaeagnus angustifolia 'Cooke's'	velvet touch Russian olive

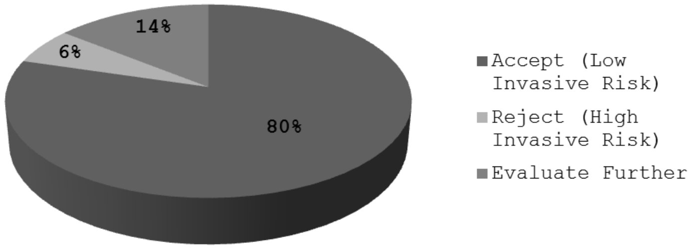

Fig. 1. Results of screenings for PlantRight PRE pilot project.

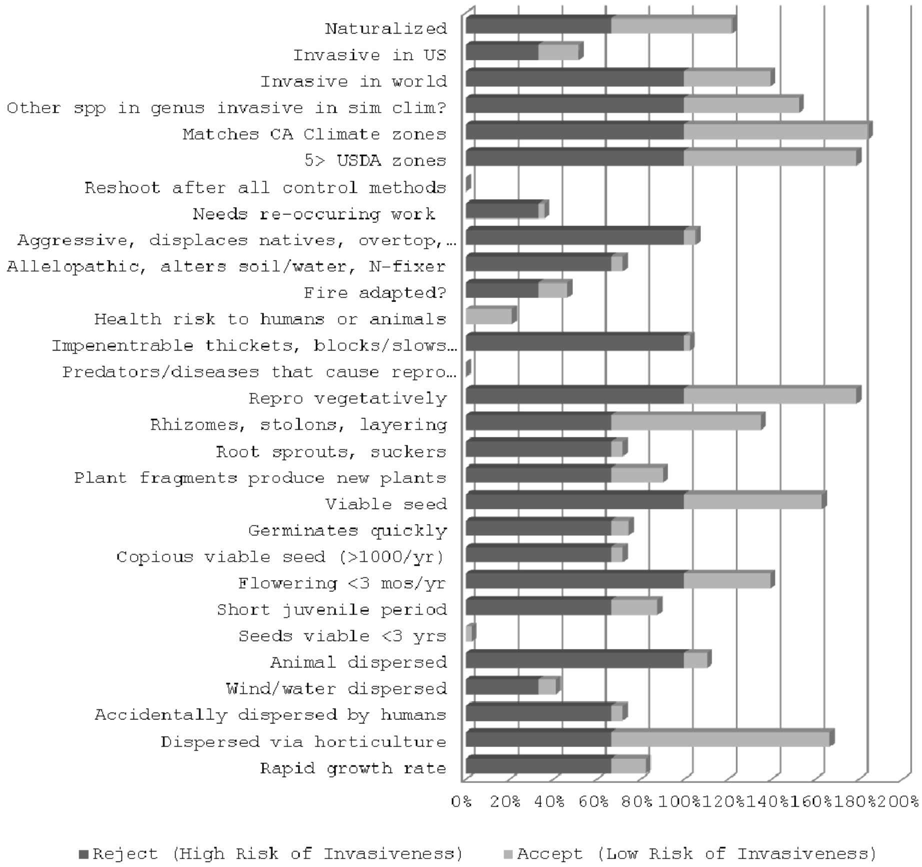

Fig. 2. Results for questions in the PlantRight PRE tool.

CONCLUSIONS

Our industry partners are excited with the project and information provided by the PRE tool. Corey Barnes, Nursery Manager for Quarryhill Botanical Garden “welcomes the opportunity to work with PlantRight to assist us in the endeavor to avoid cultivating and selling species that have the potential to escape their intended growing grounds. It seems nothing short of a win-win situation: added insurance for the status of both Quarryhill’s plant material and Quarryhill’s reputation and increased security for the native flora of

California.” We are inviting propagators or growers to join us as co-designers and early adopters of the PRE tool.

QUESTIONS AND ANSWERS

Antonio Sanchez: Will this program only be for California?

Christiana Conser: The tool was originally designed for California and we’re now broadening the scope of it to include species grown elsewhere in the USA. Basically, you can calibrate the tool for whatever scale you want (statewide, regional, or national).

Antonio Sanchez: The plants that came from Monrovia, were they only from California?

Christiana Conser: Yes.

Antonio Sanchez: Do you distinguish between southern and northern California when you screen?

Christiana Conser: Yes, plus we describe the climatic zones in which they’re found.

Richard Criley: In Hawaii, our risk assessment process consists of 49 questions. Usually, their turn-around takes a couple days. How can you run your risk assessment in just a few hours?

Christiana Conser: Our tool has been simplified to 29 questions. I, along with another U.C. Davis research assistant, do all the screening and that’s how long they take. Maybe we’ve gotten faster at it since we’ve done so many. We have access to really good resources like the U.C. Davis Arboretum and the Herbarium. As we conduct the screening we do a literature search and we document the source of each bit of information we use in the screening. That provides a way for anyone to check our findings. Other programs doing this kind of screening all have their own process and we’ve found ours to be quite effective.

Richard Criley: In the context of these screenings, how do you define “environment”? Are you referring to the natural environment or a created urban environment or some other?

Christiana Conser: We are only looking to see to what extent the plant in question will be invasive in a garden or landscape setting. We’re primarily concerned with determining the likelihood of the plant escaping out of cultivation into the wild where it would have much less cultivation and irrigation.

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Nuggets of Knowledge: Rose Thorn Disease©

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DISEASE PREVENTION IN PROPAGATION (PERSONNEL)

We all agree propagators should be concerned with the health of their plants in all stages of propagation and production. We know that the three points on the disease triangle are: Susceptible host, virulent pathogen, and favorable conditions.

We have the most control over the presence (ideally the absence) of pathogens and the actual conditions for our crops, striving always to prevent conditions favorable to harmful organisms. We talk a lot about sanitation and plant health in propagation.

Today I want to share, from personal experience, a story about the health and vigor of a certain propagator (me), and how a "plant-based" disease caused no little consternation for over 4 years until it was properly diagnosed and treated.

MY VERY OWN DISEASE TRIANGLE

1) Susceptible host = Me
2) Favorable conditions = Compromised immune system (recently discovered, 5 years ago, gluten intolerance, now resolved).
3) Virulent pathogen = "Rose Thorn Disease" = Sporotrichosis, a fungal disease which causal organism is called *Sporothrix schenckii*.

Causes of Sporotrichosis

Sporotrichosis usually begins when mold spores are forced under the skin by a rose thorn or sharp stick. The infection can also begin in apparently unbroken skin after contact with hay or moss carrying the mold. Farmers, nursery workers, landscapers, and gardeners are at higher risk for the disease. More rarely, cats or armadillos can transmit the disease. In very rare cases, the organism can be inhaled or ingested, leading to infection of parts of the body other than the skin. The disease does not appear to be transmitted from person to person.

Symptoms of Sporotrichosis

Some symptoms of sporotrichosis and characteristics of the infection include:

- Once the mold spores move into the skin, the disease takes days-to-months to develop.
- The first symptom is a firm bump (nodule) on the skin that can range in color from pink to nearly purple (Fig. 1). The nodule is usually painless or only mildly tender.
- Over time, the nodule may develop an open sore (ulcer) that may drain clear fluid. Untreated, the nodule and the ulcer become chronic and may remain unchanged for years.
- In about 60% of cases, the mold spreads along the lymph nodes.
- Over time, new nodules and ulcers spread in a line up the infected arm or leg. These can also last for years. In very rare cases, the infection can spread to other parts of the body.
- The disease can infect the bones, joints, lungs, and brain.
- Such spreading usually occurs only in people with a weakened immune system. These infections can be life threatening and are difficult to treat.

Fig. 1. Rash that developed on author's hands as a result of sporotrichosis.

Treatment of Sporotrichosis

If you have any weird, persistent rash, or any of the symptoms described above, see your doctor. Consult a dermatologist. Tell your doctors that you are a horticulturist and that you work with sharp objects, sphagnum or peat moss, soils, thorny plants, etc.

The therapy prescribed in my case was an oral antifungal called itraconazole. This drug was effective; the symptoms are gone and the disease is no longer in my skin. There may be side effects to be aware of. This is not to be construed as my recommendation to use a drug, rather a report on my case of rose thorn disease.

Prevention of Sporotrichosis

There is no vaccine to prevent sporotrichosis. You can reduce your risk of sporotrichosis by wearing protective clothing such as gloves and long sleeves when handling wires, rose bushes, bales of hay, pine seedlings, or other materials that may cause minor cuts or punctures in the skin. It is also advisable to avoid skin contact with sphagnum moss.

SUMMARY

Watch out for plant diseases on your plants ... and in your body too.

The Power of Intention©

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The following is the most powerful and important tool I have in my personal and professional toolbox. It is the central driver that has allowed us to overcome amazing obstacles in order to develop Microplant Nurseries into a successful company focused on the commercial micropropagation of (mostly woody) plants.

MY NUGGET IS ABOUT MAKING THINGS HAPPEN

During our IPPS meeting in Portland this year, I asked our entire group to help illustrate my message and they did it with gusto. When I asked everyone to get up and move to one side of the room, it took 23 s for about 100 people to get there. I didn't even ask them to do it quickly! The challenge given was for each person to cross the room in a different way than those who went before them. How many ways are there to cross a room? It took about 20 min, helped along with some lively rock and roll music and the results were often hysterically funny. Cartwheels, jumping jacks, zigzag, with cell phones, bumping into walls, hopping, skipping, hopping backwards, oogling your spouse with binoculars (thanks Mike Evans!) reading a newspaper, yoga, queenie waves…on and on it went.

The point of it all was this:

1) If You Intend to Do Something…You Will. The most important step is deciding to do it. One of the best examples I know of, is Diana Nyad. She intended to swim from Cuba to Florida. She declared it to herself. She didn't try to do it, she intended to do it. Nobody gets things done by "trying" to do them.
2) The Rest Is Just Mechanics. How you get there is just something you need to figure out. We often focus on the struggle with the "how" part of the equation and choose to give up because we can't see the answer right away. If you give up, that's OK, just recognize that you didn't intend to get there in the first place. Own your choices.
3) What Do You Let Get In Your Way? Sometimes there may be roadblocks or rocks in the way. Realize they are just rocks. If you really intend to get there, you are going to have to come up with a way to get around them. Diana Nyad ran into many obstacles on her swim. She made several attempts over the years. Sharks, jelly fish, dehydration and fatigue were all problems she had to overcome. Eventually she got there. It was her fifth attempt. She was 64 years old.

Sometimes those roadblocks are people…like your boss or the bank telling you there isn't enough money to buy that critical new piece of equipment, or you can't hire more people to get the job done, or your spouse thinking they know the way to the concert, but they really don't. Sometimes the roadblock is our own head…not smart enough, not strong enough…choosing to believe it when someone knocks down your brilliant idea. The very hardest part in capturing the power of intention is in realizing that it is nobody else's fault if you don't get there. The key word is YOU. What do YOU let get in your way? If you can't afford that new piece of equipment or more labor, what is your next plan to get the job done? And why did you not drive the car to the concert yourself, or have the directions handy, or make sure you left the house earlier? If the group shoots your idea down, and you know you had the answer, why did you not choose to come up with a different way to get the team to understand? Own the fact that you never intended to get there, don't blame others.

Once you see the obstacles as just things to get around, the getting around can be so much fun to create.

Be a Soft Rock

Many of us are in leadership positions in our companies. Pay attention to those moments that you throw roadblocks in front of others. Encourage folks to find their way around you by suggesting alternatives or simply expressing the confidence you have that a solution is possible.

It is amazing what the people in your life can accomplish if you simply get out of the way and cheer them on to the other side of the room.

Construction of a Bench Plastic Cover for Maintaining High Relative Humidity©

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Fall Creek Farm and Nursery is a wholesale grower of blueberry plants. Most of our plants are derived from tissue culture. The plants we grow are made from Stage 2 in vitro plants. This means the plant is a microcutting without roots. In order to acclimate these plants to life outside the test tube they are planted into trays that are then kept in incubation tents inside the greenhouse (Fig. 1). These tents are basically a small greenhouse that can be sealed to keep the humidity high and the temperature warm mimicking the in vitro environment.

There are many different styles of tents that can be used for this process, from simple to elaborate. Since we grow so many plants in this manner I looked for a repeatable, simple-to-access, and easy-to-sanitize system. I found that portable outdoor canopy makers have a straightforward system utilizing pre-made connections that can be used to assemble these incubator tents. I use electrical metallic tubing (EMT) to attach the canopy connectors to form the structure of the tents (Fig. 2).

I have sourced the canopy connectors through a vendor I found on the Internet. Their name is "Yuma's Bargain Warehouse". I found the people there very easy to work with and was able to make my purchases with them over the phone.

To connect poly film to the EMT pipe I have been using a plastic PVC clip called a "Snap Clamp". The clamps are an easy solution for attaching poly film to pipe. These clamps are available through a website called the "Greenhouse Megastore". This company is a source for many hard-to-find tools and equipment for the nursery trade.

The benches in our greenhouses are 6 ft. wide by 25 ft. Long. To make a tent that covers these benches requires about $100 in parts. These canopy parts and snap clamps have simplified a process that in the past had required much more time and effort.

Figure 3 shows a finished plastic tent and how the top can be rolled back to slowly increase the relative humidity inside.

Fig. 1. Completed plastic tent cover for a greenhouse bench.

Fig. 2. Conduit electrical metallic tubing connectors used for the construction of the plastic tent.

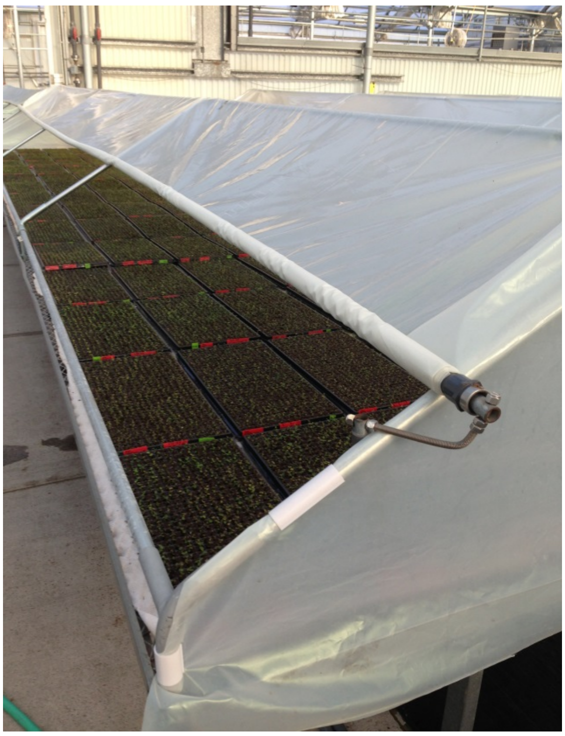

Fig. 3. Finished plastic tent in use showing how the top can be rolled back to slowly increase the relative humidity inside.

All-America Selections Winners for 2013: Outstanding Performers for the Home Garden©

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Eight cultivars became All-America Selections (AAS) Award Winners in 2013. All-America Selections includes a network of over 50 trial grounds all over North America where new, never-before-sold introductions are "Tested Nationally and Proven Locally®" by skilled, impartial AAS judges. Only the best performers are declared AAS Winners. All-America Selections continues as the oldest, most established international testing organization in North America.

The All-America Selections winners for 2013 are as follows:

CANNA 'SOUTH PACIFIC SCARLET' (F_1 CANNA)

This cultivar is grown from seed, not tubers. Plants are compact in habit and well-suited for both landscape and container use. 'South Pacific Scarlet' canna prefers warm and humid conditions over 77°F. This cultivar is more vigorous, more uniform, and has more basal branching than *C.* 'Tropical Red'. Bred by Takii & Co., Ltd.

CITRULLUS LANATUS 'HARVEST MOON' (F_1 WATERMELON)

This is the first-ever hybrid, triploid, seedless watermelon to win an AAS Award. Similar to the popular heirloom cultivar 'Moon and Stars', 'Harvest Moon' is an improvement in that it features healthy, shorter vines that produce better tasting, medium-sized fruits with sweet, crisp, pinkish-red flesh. Bred by Seeds By Design/K&B Development.

CUCUMIS MELO 'MELEMON' (F_1 MELON)

This melon features earliness, high yield, and superior taste on healthy, strong plants. Uniform, personal-sized fruits have a taste similar to honeydew, but with a surprising and delicious tanginess. This cultivar is suitable for home gardeners and market growers. Bred by Known-You Seed Co., Ltd.

ECHINACEA 'CHEYENNE SPIRIT' (CONEFLOWER)

This stunning first-year flowering coneflower captures the spirit of the North American plains by producing a delightful mix of flower colors from rich purple, pink, red, and orange tones to lighter yellows, creams, and white. This wide range of flower colors on well-branched, durable plants are sure to please the color preferences of any gardener. As an added bonus, 'Cheyenne Spirit' coneflower does not require a lot of water and offers a wide range of uses from the perennial border, in a mass landscape planting, in a butterfly garden or as a cut flower. Bred by Kieft Seed.

PELARGONIUM 'PINTO PREMIUM WHITE TO ROSE' (F_1 GERANIUM)

Flowers feature a unique coloration with petals starting out white, then deepening to rose-pink as the flowers mature, giving an attractive bicolor effect. Dense, well-branched plants sport deep green leaves with darker zones that contrast beautifully with the light colored flowers. Bred by Syngenta Flowers, Inc.

***SOLANUM LYCOPERSICUM* ‘JASPER’ (F_1 TOMATO)**
This tomato produces high yields of uniform fruit with excellent taste and a long harvest window on vigorous, fusarium-resistant plants. Fruits stay on the vine and then hold well after ripening both on the vine and post-harvest. Bred by Johnny’s Selected Seeds.

***ZINNIA HYBRIDA* ‘PROFUSION DOUBLE DEEP SALMON’ (ZINNIA)**
This cultivar features intensely vibrant, deep pink-orange flowers with double petals. Plants are self-cleaning, disease resistant, and grow well in a range of climates, including areas with high night temperatures. The flowers can grow 2½ to 3 in. in diameter. Bred by Sakata Seed Corp.

***ZINNIA HYBRIDA* ‘PROFUSION DOUBLE HOT CHERRY’ (ZINNIA)**
This zinnia produces rich rose, double-petalled blooms that cover the plants with flowers from spring through frost. The bright color of the 2½ to 3 in. flowers does not fade, even under high temperatures. Like all Profusion zinnias, ‘Profusion Double Hot Cherry’ is easy to grow as it is self-cleaning, disease resistant, and grows well in a wide range of climates. Bred by Sakata Seed Corp.

In Summer 2013, the following two 2014 AAS Winners were also announced:

***GAURA LINDHEIMERI* ‘SPARKLE WHITE’ (GAURA)**
This gaura produces long, slender stems sporting a large number of dainty white flowers tinged with a pink blush. Plants perform well when mass planted in sunny landscape beds, in groupings with other perennials, or in larger containers. This season-long bloomer also has excellent heat tolerance and a more uniform flowering habit than other seed-grown gauras. Bred by Kieft Seed.

***PHASEOLUS VULGARIS* ‘MASCOTTE’ (BUSH BEAN)**
The first AAS-winning bean since 1991, this compact cultivar is perfect for today’s small-space gardens. ‘Mascotte’ is a bush-type bean that produces long, slender pods that stay above the foliage for easy harvest. This bean also has white showy flowers for ornamental value during bloom time. Bred by Clause Vegetable Seed.

More information on AAS and AAS winners is available at: <www.all-americaselections.org> or <www.aaswinners.com>.

Comparative Rooting Response of Cuttings Using a Basal Quick-Dip in Two Water-Soluble Forms of IBA©

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A question posed by commercial nursery growers as to whether rooting results obtained in cutting propagation using auxin solutions made with Hortus IBA Water Soluble Salts [an EPA-registered product which forms the potassium salt of indole-3-butyric acid (K-IBA) when dissolved in water] would be comparable to results obtaining using technical grade K-IBA (available for research use, but not EPA-registered for commercial use) prompted this study. Solutions were prepared using these two products at five rates of IBA: 500, 1000, 1500, 2000, and 3000 ppm. Subterminal (3-node) cuttings of *Ligustrum japonicum* 'Texanum' (Texas privet), single-node cuttings of *Rosa* 'Moorcap' Red Cascade® (rose), and subterminal (2-node) cuttings of *Trachelospermum jasminoides* (star jasmine) received a 1-s basal quick-dip in one of the 10 auxin solutions. Cuttings of all three crops showed no significant difference in rooting response between the two products. Results indicate that commercial propagators can switch from K-IBA to Hortus Water Soluble Salts for a basal quick-dip without an adjustment in IBA rate.

INTRODUCTION

Thimann and Koepfli (1935) reported the synthetic preparation of the auxin indole-3-acetic acid (IAA), a naturally occurring substance that had recently been found to have root-forming properties, and demonstrated its practical use in stimulating root formation on cuttings. Soon after, the synthetic auxins indole-3-butyric acid (IBA; now known to occur in plants) and 1-naphthaleneacetic acid (NAA) were shown to be more effective than IAA for rooting cuttings (Zimmerman and Wilcoxon, 1935). Currently IBA and NAA are the most widely used auxins for promoting root formation on stem cuttings (Blythe et al., 2007). Auxin treatments are commonly used in commercial plant propagation to increase overall rooting percentages, hasten root initiation, increase the number and quality of roots, and encourage uniformity of rooting (Hartmann et al., 2011; Macdonald, 1987). Commercial root-promoting products ("rooting hormones") are available in various formulations: liquid concentrates, water-soluble salts and tablets, gels, and powder (talc) (Blythe et al., 2007).

Some growers have used the potassium (K) salt of IBA (K-IBA) over the years for preparation of water-based IBA solutions. Technical grade K-IBA is commonly used in plant propagation research; however, this product, previously purchased by growers from scientific supply companies, is no longer available for sale for use as a root-promoting compound due to lack of Environmental Protection Agency (EPA) registration. One EPA-registered product that can be used as an alternative to K-IBA is Hortus IBA Water Soluble Salts (containing 20% IBA, a pH buffer, and proprietary ingredients; Phytotronics Inc., Earth City, Missouri), which produces K-IBA when the product is dissolved in water.

Commercial nursery growers have questioned whether rooting results obtained using auxin solutions made with Hortus IBA Water Soluble Salts are comparable to results obtained using technical K-IBA. The current study was conducted to examine this issue using cuttings of three commonly grown nursery crops.

MATERIALS AND METHODS

Solutions of K-IBA (Sigma, St. Louis, Missouri) and Hortus IBA Water Soluble Salts were prepared at five rates of IBA: 500, 1000, 1500, 2000, and 3000 ppm (total of ten treatments). Subterminal (3-node, 3.5-in.) cuttings of *Ligustrum japonicum* 'Texanum'

(Texas privet), single-node (1-in.) cuttings of *Rosa* ' Moorcap' Red Cascade® (rose), and subterminal (2-node, 2.75-in.) cuttings of *Trachelospermum jasminoides* (star jasmine) were prepared on 8 July 2012, received a 1-sec basal quick-dip in one of the 10 auxin solutions (30 cuttings per treatment), stuck in Sunshine Redi-earth Professional Growing Mix in 50-cell plug trays, and rooted in a greenhouse under intermittent mist for 6 to 7 weeks.

Upon harvest, root systems were washed to remove rooting substrate, then scanned and analyzed with WinRHIZO software (Regent Instruments Inc., Quebec, Canada) to determine total root length. Roots emerging from rooted cuttings were counted. Linear models were used to analyze total root-length data with the GLIMMIX procedure of SAS (SAS Institute Inc., Cary, North Carolina). Generalized linear mixed models were used to analyze root count data with the Poisson distribution (rose) or negative binomial distribution (Texas privet and star jasmine) with the GLIMMIX procedure of SAS. Models included auxin rate (quantitative) and IBA source (qualitative). There were no significant interactions between auxin rate and IBA source.

RESULTS AND DISCUSSION

Upon harvest, cuttings of Texas privet exhibited no significant difference in number of roots or total root length between the two products or among the different rates of IBA (Table 1). Cuttings of rose exhibited no significant difference in number of roots and a marginally significant increase in total root length using the Hortus product compared with technical K-IBA; number of roots and total root length showed highly significant and marginal increases, respectively, with increasing rate of IBA with both products. Cuttings of star jasmine exhibited no significant differences in number of roots or total root length between the two products, but significant increases with increasing rate of IBA with both products. Results indicate that commercial propagators can switch from K-IBA to Hortus Water Soluble Salts for a basal quick-dip without an adjustment in IBA rate.

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Table 1. Rooting response of cuttings of *Ligustrum japonicum* 'Texanum' (Texas privet), *Rosa* 'Moorcap' Red Cascade® rose, and *Trachelospermum jasminoides* (star jasmine) obtained using a basal quick-dip in solutions of the potassium salt of IBA (K-IBA) or Hortus IBA Water Soluble Salts (WSS) (each prepared at 500, 1000, 1500, 2000, and 3000 ppm IBA) and rooted under intermittent mist in a greenhouse (n=30).

	IBA rate	Roots (no.)		Total root length (cm)	
	(ppm)	K-IBA	WSS	K-IBA	WSS
Ligustrum japonicum	500	8.1	7.9	80	93
'Texanum'	1000	8.3	7.7	88	81
	1500	8.3	8.2	91	88
	2000	7.7	8.3	85	86
	3000	8.3	7.6	91	92
Significance[z]:					
Auxin type		NS		NS	
Auxin rate		NS		NS	
Rosa 'Moorcap' Red	500	3.1	3.4	51	57
Cascade® rose	1000	3.6	3.2	52	61
	1500	3.6	3.8	56	63
	2000	4.1	4.2	60	60
	3000	4.7	5.6	59	65
Significance:					
Auxin type		NS		*	
Auxin rate		***		*	
Trachelospermum	500	3.3	4.1	87	95
jasminoides	1000	4.5	4.4	112	108
	1500	5.5	5.1	115	101
	2000	5.5	4.8	130	127
	3000	6.0	5.7	169	151
Significance:					
Auxin type		NS		NS	
Auxin rate		***		***	

[z]Not significant or significant at α = 0.05 (*), 0.01 (**), or 0.001 (***).

Innovative Techniques to Capture and Re-Use Water for Small Scale Nurseries in Washington State©

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The Washington State Department of Ecology (WSDE) has set very strict standards for utilization of both ground water and surface water. In the absence of a valid Water Right Permit rural landowners can only draw up to 5,000 gal per day from a well. In 2009, however, WSDE passed a new law stating that the landowners can capture rainwater (rain water harvesting) from their farm buildings and use it for irrigation purposes, without having to go through the elaborate process of applying for and possibly being denied a Water Right permit. By digging a relatively small water collection basin on their land, ornamental plant growers can collect and re-use rainwater thus ensuring adequate water for their operations.

INTRODUCTION

All too often rural landowners assume that owning a piece of property is equivalent to having access to the ground and/or surface water on their property. The right to use the water on the property should be viewed in terms of a lease, an easement, or a license, not ownership.

Water Rights

In Washington, water codes were established in 1917 for surface water and in 1945 for ground water. To obtain a new water right, landowners must file a claim with The Washington State Department of Ecology (WSDE). There are over 7,000 requests for new Water rights in Washington State. It may take 10 years for a new request to be reviewed; there is no certainty that a new request will be granted. The Washington State Department of Ecology has an on-line searchable database that lists the properties that have valid water rights.

Exempt Wells

Rural landowners can utilize up to 5,000 gal of water/day from a dug well when they lack a Water Right Permit. There is no acreage limit. The Washington State Department of Ecology must be notified 72 h before drilling any well. In terms of rain water harvesting (RWH) the use of the Exempt Well water can be added to the rain water collection system during the off-season.

Rainwater Capture

In 2009 WSDE issued a new interpretive policy that allows landowners to collect rooftop or guzzler water and use it for irrigation (WA Ecology RWH 2013). There are no limitations on the use of RWH collected water.

Rainwater Storage

Ecology states that RWH storage systems can be used for both water collected from structures, as well as the ground water pumped from Exempt Wells. The limit on RWH is 10 acre-ft of water. A one-acre pond (208 ft on a side), and 10 ft deep would hold 10 acre-ft of water, which is equivalent to 3.26 million gal of water. A one-acre pond would be a sizable investment for the limited acreage land-owner.

IN THE ABSSENCE OF A WATER RIGHT

Field Production

Washington state growers can purchase woody liner stock from Oregon wholesalers and grow them to maturity to supply the local landscaper trade. In-ground stock requires considerably less water than above-ground container stock.

Larger Containers

A one-acre can yard with roadbeds and utility areas could hold 21,780, 1-gal containers and require 27,000 gal of water per day. Conversely, a one-acre can yard could hold 2,062, 10-gal pots, requiring 1.25 gal of water per pot per day for a total of 2,577 gal. Without a Water Right Permit the use of small containers would not be feasible.

Pot in Pot

For a nursery with 15-gal socket/liner pots Northwest shade tree growers have found that they only require 1 gal of water per day, which is half the amount for a comparable tree grown in an above-ground pot.

Drought Tolerant Plants

With a limited supply of supplemental water for irrigation, growers can elect to raise conifers, evergreen shrubs, native plants, and ornamental shade trees as opposed to herbaceous perennials which require significantly more water.

CAPTURE AND RE-USE

Silos

Water silos can be free standing or attached to roof gutters. Ranging in size from 10,000 to 60,000 gal they might serve a small greenhouse operation. At a built cost of $1/gal they are too expensive for container yard or field producers. Besides, they would not hold enough water for field or above ground containers. Summers are typically very dry in western Washington.

Pond Limits

While one can store up to 10 acre-ft of water the size of this pond would certainly be a consideration on a 5-10 acre parcel.

Embankment Pond

The least expensive RWH pond would consist of building a dam on a gently sloping piece of ground and impounding the water that is collected (Fig. 1). Ecology states that the outlet dam should not exceed 10 ft in height before a Dam Safety permit is required.

Levee Pond

A levee pond is defined as an above-ground excavated pond. Levee ponds are only built on flat ground (Fig. 2). Levee ponds cannot be excavated to a depth of more than 10 ft according to Ecology. Unless the soil has 20% clay content, a 60 mil liner may be needed to prevent leakage on well-drained sites. Alternatively, utilizing clay subsoil or a bentonite clay application would eliminate the need for a liner.

Fig. 1. An embankment pond can be used for rainwater harvesting and as a filter for runoff from field stock.

Fig. 2. A fully lined levee pond directly adjacent to a large commercial greenhouse serves as an excellent rainwater harvesting collection basin.

RAINWATER HARVESTING FROM THE ROOF OF A GREENHOUSE

Rainwater Harvesting Calculations

Outbuildings and greenhouses structures are ideally suited to RWH. When constructed with gutters and downspouts they can easily funnel water to a collection basin.

Math

First, determine the square footage of the impervious surface (greenhouse roof, out-building). Next, look up the annual precipitation amount from the National Weather Service. Multiply the catchment area (ft^2) × rainfall depth in inches × 0.623 conversion factor. For example 1 in. of rain on 1,000 square ft of collection area yields 600 gal of collectable rainwater. A 30 ft wide by 100 ft long gable roof greenhouse may have 3,600 sq. ft. of roof surface. With 40 in. of annual precipitation a greenhouse this size could capture nearly 90,000 gal of water per year if it is equipped with gutters and downspouts.

CLEAN-UP AND RECIRCULATION FROM RAINWATER HARVESTING AND PONDS

Currently, the Washington State Department of Ecology does not require that Washington nurseries collect the sediment, nutrients, or pesticides that run off from field or container nurseries. Presently only Oregon and California require this practice. Runoff is mixed with fresh water and then reapplied to the growing beds. Rainwater harvesting ponds can capture not only water from greenhouses and sheds, but also the water, pesticides, and nutrients from can yards. With good filtration this water can be re-applied back onto the nursery (Johnson et al., 2011).

RAINWATER HARVESTING ENGINEERING REQUIREMENTS

Grading and Inspection Fees

A grading and drainage permit is generally required when more than 200 cubic yd of soil is moved. Growers will need to consult with their local Public Works engineering department to determine the costs. Once completed ponds will need to inspected to ensure that they have been properly sized.

Pond Limitations

If more than 5,000 yd^3 of soil is moved the pond will need to be designed by a civil engineer, thus significantly increasing the project costs.

STATE ENVIRONMENTAL POLICY ACT CHECKLIST

In 1971 the WA State Department of Ecology developed the State Environmental Policy Act (SEPA) to ensure environmental protection was ensured for all elements of the built environment. A SEPA checklist is required when the county engineering department receives a grading permit. County staff is required to submit the application to Ecology for their review. Small projects may not require a SEPA checklist. Ecology states that they can handle most applications within 2-3 months. The landowner will need to provide a detailed plan of the project including any changes to the land that would include grading or filling. The applicant would need to provide the cubic yards of excavation and the square footage of the RWH catchment basin.

ACTIVITIES NEAR RIPARIAN AREAS

In Washington State, county government is bound by strict adherence to the Growth Management Act which acts to preserve critical habitat for fish and wildlife. Agricultural producers are bound by varying buffer widths along salmon bearing streams, as determined by the Washington State Department of Fish and Wildlife. Growers should consult with Ecology before implementing RWH near a riparian area.

TECHNICAL ASSISTANCE

USDA Natural Resources Conservation Service

NRCS staff are non-regulatory advisors who can provide technical assistance to farmers who want to plan and design a farm pond to store rainwater (NRCS, 2000).

Water Rights Explorer

The Washington State Department of Ecology maintains a searchable database utilizing Geographical Information Services of existing water rights that landowners can refer to. One can search by parcel, range and section (WA Ecology Water Right Explorer, 2013).

Washington State Governor's Office of Regulatory Assistance
This public agency can help landowners understand how to apply for a Water Right, dig a well, and obtain a dam construction permit. All of their services are free and one can schedule a walk-in visit with a staff member. Their toll-free number is 1-800-917-0043, and their e-mail is <help@ora.wa.gov>. This office is located in Olympia, Washington.

RAINWATER HARVESTING COSTS

Pond Size
For this exercise we will build a square pond 116 ft on side and dig it 10 ft deep. With 27 ft^3/yd^3 our hypothetical pond comes to nearly 5,000 yd^3.

Pond Construction Costs
At $\$3/yd^3$ the construction cost is $15,000. If the site drains freely a 60-mil plastic liner may be needed; it could cost nearly $10,000 for materials and installation. In southwest Washington Permit Fees (grading and inspection) for this sized pond comes to nearly $5,000 with insurance. SEPA fees would be variable.

RAINWATER HARVESTING POTENTIAL ACREAGE

Container Nurseries
With 1 million gal at the start of the irrigation season (mid-May) Table 1 depicts the size and number of containers that can be irrigated from an RWH collection pond.

Table 1. The use of rainwater harvesting to supply a container nursery.

Pot size in gal	Pots per acre	Gal per day (5/15-10/1)	Number of irrigation days	Total demand in gal	Number of acres
	4,640	1.25	130	754,000	1.3
10	2,062	1.50	130	402,090	2.5
15	742	1.75	130	168,805	6.0

The data in Table 1 is based upon Oregon and Washington grower reports of water usage. Natural evaporation from the pond would be offset by the addition 5,000 gal/day from Exempt Well pumping.

Field Nurseries
Northwest, in-ground, woody-ornamental, field growers can have a much larger nursery based on the reduced need for supplemental irrigation. Table 2 depicts the size of the potential acreage if the RWH collection pond held 1 million gal at the start of the season. Field growers will need to utilize hard hose drip tubing to irrigate their rows of trees and shrubs only, leaving the ally-way dry (LeBude and Bilderback, 2008). This practice helps cut down on weed growth in the rows. Heavy-wall tubing is strong enough to last more than one production cycle. It can also be moved easily during field digging by hand or with the use of tree spades.

Table 2. The use of rainwater harvesting to supply irrigation for an in-ground field nursery.

Drip tubing for a 10-ft row spacing	Total gal	Run time (h)	Sets per week	Total gal per week	Total weeks	Total gal per acre	Acres
27 gal/100 ft/h	1,176 gal[1]	2	2	4,704	18	84,472	11.8

[1]An acre of ground is 208 ft on a side. At 10-ft row spacing, there will be 21 drip hose lines per acre.

FUTURE DIRECTIONS

Support from Ecology

There is strong support from Ecology for RWH. Unless there are cumulative impacts from larger rainwater collection systems on streams and groundwater supplies, landowners should be able to rely on RWH as a feasible alternative to applying for a Water Right Permit. Ecology states that larger catchment basins will be viewed as surface water. Under the terms of RCW 90.03 users who take surface water will need to apply for a Water Right permit.

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‘Ebony Fire’, ‘Ebony Flame’, Ebony Embers’, ‘Ebony & Ivory’, and ‘Ebony Glow’: Five New Dark-Leaved Crape Myrtles©

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The Agricultural Research Service, USDA, has developed and released five dark-leaf crape myrtles: ‘Ebony Fire’, ‘Ebony Flame’, Ebony Embers’, ‘Ebony & Ivory’, and ‘Ebony Glow’. The cultivars are predominantly *Lagerstroemia indica* in heritage. As with most hardy crapemyrtle cultivars, selections are generally top hardy in USDA Hardiness Zone 7 and root hardy to Zone 6 if properly hardened for winter conditions. Plants have exceptional flowers and outstanding disease resistant foliage which maintains its dark color throughout the summer. Plants start flowering in south Mississippi in late June, with best flowering and most intense foliage color displayed when plants are grown in full sun. ‘Ebony Fire’ is first to flower while ‘Ebony Embers’ is last to begin flowering.

All cultivars display dense crown branching with excellent foliage coverage. ‘Ebony Flame’ and ‘Ebony & Ivory’ have upright growth habits, while ‘Ebony Glow’ is upright spreading, ‘Ebony Embers’ is vase shaped, and ‘Ebony Fire’ is globe shaped. Plants are projected to mature at 20 ft in most plantings, but can be easily maintained at a smaller size with a winter pruning to reduce plant proportions. The five Ebony selections are also being marketed under the Black Diamond™ (BD) trademark as: ‘Ebony Glow’ (Black Diamond™ Blush), ‘Ebony & Ivory’ (Black Diamond™ Pure White), ‘Ebony Fire’ (Black Diamond™ Crimson Red), ‘Ebony Flame’ (Black Diamond™ Best Red), and ‘Ebony Embers’ (Black Diamond™ Red Hot).

Additional information on ‘Ebony Embers’, ‘Ebony Fire’, ‘Ebony Flame’, ‘Ebony Glow’ and ‘Ebony & Ivory’ crapemyrtles and a list of nurseries propagating them are available upon written request to Cecil Pounders; USDA-ARS [Cecil.Pounders@ars.usda.gov]. The USDA-ARS does not have plants for sale. Specimens of the five cultivars have been deposited in the National Plant Germplasm System as ‘Ebony Embers’ (NA 81466, PI 668407), ‘Ebony Fire’ (NA 81467, PI 668408), ‘Ebony Flame’ (NA 81468, PI 668409), ‘Ebony Glow’ (NA 81469, PI 668410), and ‘Ebony & Ivory’ (NA 81465, PI 668406).

Cutting Propagation of Little-Leaf Mountain Mahogany©

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Superior selections of little-leaf mountain mahogany (*Cercocarpus ledifolius* var. *intricatus*) (CLI) have potential for use in water-conserving landscapes in the Intermountain region of the USA. The potential for propagating CLI by cuttings was determined by selecting specimens from a range of sources and growing conditions at different seasons and with different rooting conditions in a series of individual experiments. Exogenous auxin treatments at high (4000/2000 ppm indolebutryic acid/naphthaleneacetic acid as Dip-N-Grow®) and low (2000/1000 ppm of the same material) were also tested. Selection CLI-1 (wild source, Ephraim, Utah, Jan. 2010) rooted at 0, 33, and 42% with zero, low, and high auxin treatments. Selections CLI-2 and CLI-3 (wild source, Mt. Charleston, Nevada, May, 2010) had results of 0, 0, and 8% and 15, 28, and 52% rooting for the respective auxin treatments and selections. Selection CLI-4 (landscape source, Logan, Utah, July, 2010) had 8, 96, and 100% rooting for similar auxin treatments. Finally selections CLI-5 and CLI-6 (landscape source, Logan, Utah) and CLI-3 (container-grown stock plants) stuck in July, 2012 had 6, 2, and 85% rooting with the low rate of auxin, respectively. Overall, two selections had greater than 90% rooting while one had approximately 40% and three others less than 10%. For the three selections that did root, supplemental auxin increased the percentage of rooted cuttings from 0-15% for untreated controls to 42-100% for treated. In contrast, the three selections with poor rooting had little response to exogenous auxin at the levels used. Propagation of CLI by cuttings is feasible, though variable. The variability may be due to accession genetic differences, stock plant growing conditions, or rooting conditions.

Development of Autopolyploid *Syringa reticulata* subsp. *pekinensis* for Breeding©

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INTRODUCTION

Tree lilacs are generally considered to be popular and smart choices for street and utility plantings because of their hardiness, rugged nature, and ability to thrive under adverse urban conditions. In particular cultivars of the Japanese tree lilac (*Syringa reticulata* subsp. *reticulata* (Blume) H. Hara) and Peking lilac (*S. reticulata* subsp. *pekinensis* Rupr.) are often promoted for municipal plantings and for home use (Jull, 2011; Gerhold, 2007). Virtues of these trees include the ability for use in U.S.D.A. hardiness from Zones 3(4) through 7, tolerance to a wide range of biotic and abiotic stresses; as well as, ornamental flowering and in some cases exfoliating bark which adds to aesthetic appeal.

Syringa reticulata may be further divided into two subspecies, with *S. reticulata* subsp. *reticulata* and *S. reticulata* subsp. *amurensis* (Rupr.) P.S. Green & M.C. Chang (Li et al., 2012). *Syringa reticulata* subsp. *pekinensis* is native to northeastern China, *S. reticulata* subsp. *amurensis* native to northeastern China, Korea, and Siberia while *S. reticulata* subsp. *reticulata* is native to northern Japan. The three taxa were independently introduced to cultivation from the mid to late nineteenth century (Dirr, 2009). Under cultivation in North America, garden escapes have been documented in Massachusetts, Michigan, Minnesota, New Hampshire, New York, Pennsylvania, Vermont, Wisconsin, Wyoming, and in Ontario (Canada) (Kartesz, 2013; Schimpf et al., 2009; Jordan et al., 2008; Springer and Parfitt, 2007; Sorrie, 2005). Most of these escapes have been reported as *S. reticulata* and have occurred as few plants or self propagating in localized areas; however, sampling from escaped colonies in Minnesota suggest that the tree lilacs may be shade tolerant during invasion allowing plants to persist until a canopy openings allow for rapid growth and fruit production (Schimpf et al., 2009). Shade tolerance, along with other characteristics such as prolific seed set and tolerance to a wide range of environmental conditions may facilitate the plant's ability to seed out from original plantings to less managed areas. At the Morton Arboretum in Lisle, Illinois, seedlings are frequently observed and removed from cultivated beds (personal observations). To prevent garden escapes and to decrease land management inputs, the use of sterile or low fertility cultivars from some "weedy taxa" have been promoted within some regions (Oregon Department of Agriculture, 2013; Brand et al., 2012; Knight et al., 2011; Alvey, 2009; Gagliardi and Brand, 2007). One technique used to develop sterility is ploidy manipulation.

Ploidy refers to the number of sets of chromosomes within an organism's genome. Humans and most animals are diploid having two sets of chromosomes (2*x*), while polyploid plants (plants with more than two sets of chromosomes) occur frequently in nature. Polyploids because of their enlarged genomes often have "giga" sized cells that are larger than their diploid counterparts. The layering of the enlarged cells can impact the appearance and behavior of the polyploid plant (Kher, 1996). Plants with three sets of chromosomes are referred to as triploids (3*x*). Triploids are generally considered to be sterile because the chromosomes fail to divide evenly during meiosis. Triploids may be created by hybridization of tetraploid plants (plants with four sets of chromosomes, 4*x*) and diploid plants. In some cases such as bananas, the hybridization of two species with different ploidy levels was used successfully to created triploids that produce seedless fruit. In *Syringa* there are no reports of naturally occurring polyploids (Fiala, 1988). Artificial induction of polyploidy in *Syringa* with the chemical mutagen colchicine was successfully demonstrated by Fiala (1988) for shrub lilacs and with *S. reticulata*. Oryzalin is another chemical mutagen that is also used to produce polyploids in ornamental taxa. In comparisons between colchicine and oryzalin, oryzalin produces similar conversions to polyploidy at lower concentrations (Ascough et al., 2008; Lehrer et al., 2008).

Therefore, the goal of the research presented in this paper is to produce autotetraploid *S. reticulata* subsp. *pekinensis* with the chemical oryzalin. Tetraploid plants will then be used as breeding stock to retrieve sterile triploid selections.

MATERIALS AND METHODS

Plant Material

Four hundred open pollinated seed were collected at the Morton Arboretum in the fall of 2012 from each of three accessioned *S. reticulata* subsp. *pekinensis;* including cultivars 'Morton', China Snow™ (2391-26*1), 'Zhang Zhiming', Beijing Gold™ tree lilac (319-2002*1), and an unnamed upright selection (459-96*1). The seed were sown into flats (deep propagation flat; Anderson Die & Manufacturing, Portland, Oregon), one flat was sown for each accession, medium was a peat based potting mix. Seeded flats were watered and placed in a walk in cooler for stratification at 4°C for 90 days. After stratification the flats were moved to a glass house (74°F, with fluctuations ~60°F to 94°F) for germination and watered by hand as needed. Six days after the flats were moved to the glasshouse the first emergence was observed.

Inducing Polyploidy

At approximately 9:00 AM on the 7th day following the first emergence, when a majority of the emerging seedlings were in the cotyledon stage, the seedlings were individually plucked from the trays and evenly divided into treatment and control groups. There was one bulked treatment and one bulked control per group of seedlings. In the control groups the seedlings were soaked in deionized water while the treatment groups were soaked in 175 µm oryzalin solution (prepared from Surflan® AS; United Phoshorus, Trenton, New Jersey) for a duration of 4 h. After the treatment was complete, the seedlings were gently rinsed with DI water to remove excess treatment solution. The seedlings were then replanted in plug trays (PL-128; T.O. Plastics, Clearwater, Minnesota) with the same potting mix as above and returned to the glass house to resume growth.

Ploidy and Data Analysis

Approximately 120 days following the treatment a 10 plant sample of the control seedlings and 62 selected vigorous seedlings from the treatment groups (seedlings which had resumed growth and developed true leaves) were screened to detect ploidy levels at the University of Illinois, Roy J. Carver Biotechnology Center. For flow cytometric analysis the samples were prepared by chopping ~0.5 cm^3 leaf tissue with a razor blade in a nuclei extraction buffer (Cystain® Ultraviolet Precise P Nuclei Extraction Buffer; Partec, Münster, Germany) and stained with 4',6-diamidino-2-pheylindole (Cystain® Ultraviolet Precise P Nuclei Extraction Buffer; Partec, Münster, Germany); however, because of poor fluorescence, the samples were also over-stained with 50 ppm propidium iodide before being analyzed using a BD LSR II® flow cytometer (Becton, Dickinson and Company; San Jose, California). Data interpretation was done through review with FCS Express (DeNovo™ Software; Los Angeles, California). All samples were prepared with an internal standard to prevent peak shifting (*Pisum sativum* L. 'Ctriad'; 2C = 8.76 pg) (Greilhuber et al., 2007).

RESULTS AND DISCUSSION

Many of the treated seedlings failed to develop true leaves following the applications of oryzalin. *Syringa* seedlings treated with colchicine similarly had slow growth and development (Fiala, 1988). Because true leaves were needed for ploidy analysis, only samples of treated seedlings were able to be screened through flow cytometry. All of the control plants appeared to have the same genome size and were therefore used to set gates to identify diploid and tetraploid cells in analysis. Tetraploid plants were recovered from all three oryzalin treatments (Table 1). The conversion rate to tetraploid was similar across treatments and the combined average conversion to tetraploids was 60.3%. Some of the treated seedlings seemed unaffected by the treatments and remained diploid (2*x*) and others were chimeral with a mix of diploid and tetraploid cells (2*x* + 4*x*). A few plants appeared to be octoploid (8*x*) or mixaploids consisting of tetraploid and octoploid cells (4*x* + 8*x*). Statistical analysis was not done because treatments were not replicated within genotypes and only samples of the seedlings were screened. Even without analysis similar trends in conversion were observed across genotypes.

Phenotypic differences between polyploid and diploid plants were also observed in the treated seedlings. The tetraploids and some of the mixaploid plants appeared to have darker green leaves and felt thicker than the control and diploid seedlings (Fig. 1). These differences are attributed to increased cell size which may also alter plant behavior (Beaulieu et al., 2008). Similar changes in morphology were observed by Contreras and Ruter in treated *Cyrptomeria japonica* (L.f.) D. Don (Contreras and Ruter, 2010). Using observations based on the appearance and thickness of leaves one may be able to do a preliminary sort to discard diploid plants which had effectively escaped the treatments, although mixaploids may be distorted and closely resemble homogeneous tetraploid plants. Oryzalin proved to be very successful at inducing polyploidy in this study and the flow cytometer offered a means to quickly and accurately determine ploidy levels of the seedlings.

The next steps of the new plant development program will be to continue growing out these lilac seedlings to maturity. The plants ploidy levels will then be rescreened prior to pollinations to ensure that they have remained homogeneous tetraploids over time. The induced autotetraploid lilacs will then be used as seed parents in a series of backcrosses with pollen from diploid plants. When triploid seedlings are recovered they will be evaluated for fertility and selections will be made for ornamental characteristics.

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Table 1. Estimated ploidy levels of *Syringa reticulata* subsp. *pekinensis* seedlings after treatment with oryzalin solution.

Parent ID	Seedlings examined (no.)	$2x$	$2x + 4x$	$4x$	$4x + 8x$	$8x$
2391-26*1	30	5	4	17	2	2
459-96*1	26	6	4	15	0	1
319-2002*1	6	2	0	4	0	0
Total	62	13	8	41	2	3

Fig. 1. Visible differences between polyploid and diploid *Syringa reticulata* subsp. *pekinensis*. Diploid from control group left (lighter and thinner leaf) and autotetraploid from treatment group right (darker and thicker leaf).

New Frontiers in Magnolia Hybridization©

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On my visits to the West Coast of the USA, I was always impressed with the early blooming magnolias of subgenus *Yulania* with their gorgeous display of precocious flowers in early spring. These included *M. campbellii*, *M. sargentiana*, *M. sprengeri* , and of course the well-known *M. denudata*. Most of the USA, that has a continental climate, experience freezes that badly damage these early bloomers. Hybridizing the early bloomers in subgenus *Yulania* with some of the later bloomers in the subgenus, such as *M. liliiflora* and *M. acuminate*, can resolve that problem. We are all familiar with *M.* × *soulangeana*, a cross of *M. liliiflora* × *M. denudata* that was made over 100 years ago. These include noted cultivars such as 'Lennei', 'Brozzonii', 'Alexandrina', and other more recently selected forms.

The Brooklyn Botanic Garden was a pioneer in magnolia hybridizing with their original crosses of *M. acuminata* × *M. denudata* resulting in the well-known cultivar 'Elizabeth', as well as the lesser known *M.* × *brooklynensis* 'Evamaria' , a cross of *M. acuminata* × *M. liliiflora*. Later releases by the Brooklyn Botanic Garden include 'Yellow Bird', 'Lois', 'Judy Zuk', and 'Hattie Carthan'. Joe McDaniel, of the University of Illinois, also crossed *M. acuminata* × *M. liliiflora* which resulted in the well-known 'Woodsman'.

My work in hybridizing began when I meet two great mentors, Phil Savage in Michigan and Augie Kehr in North Carolina. Both Phil and Augie were very helpful in providing me with scions and pollen of many of their primary crosses that provided the genetic groundwork for much of my work. Phil crossed *M. acuminata* × *M. denudata* which resulted in his famous *M.* 'Butterflies'. He also made the primary crosses of *M. acuminata* × *M. campbellii*, *M. acuminata* × *M. sargentiana* var. *robusta*, *M. acuminata* × *M. sprengeri* var. *diva*, and *M. acuminata* × various *M.* × *soulangeana* cultivars. These crosses provided the genetic material for many of my future crosses. Augie Kehr also made many of these primary crosses as well as his famous 'Daybreak', a cross of 'Woodsman' × 'Tina Durio'. Augie was also involved in doubling the chromosome count of several magnolias including the famous 'Gold Cup', an octoploid with thick tepals that maintain an upright form.

Having this vast genetic pool available to me, I began my work with three primary goals in mind when hybridizing in subgenus *Yulania*:
1) Develop later blooming magnolias that will not be harmed by late spring frosts.
2) Develop magnolias that will be hardy in a U.S.D.A. Zones 4 and 5 environments.
3) Extend the blooming period of magnolias.

Using late blooming *M. acuminata* and *M. liliiflora* in subgenus *Yulania* can achieve the first and second goals, but they also pose disadvantages that need to be overcome. *Magnolia acuminata* has small greenish yellow flowers that tend to be hidden by its leaves and can bring a dull brown color to the resulting hybrids. The deep purple color of *M. liliiflora* can dominate the delicate pink color of some of the species in the subgenus. While crossing the two generally will result in a muddy purple flower like 'Woodsman' or a yellow flower like 'Yellow Bird', both can produce excellent hybrids in the succeeding generation. This is illustrated in 'Daybreak', where 'Woodsman' is the seed parent, and in 'Blushing Belle', where 'Yellow Bird' is the seed parent. Other hybrids that are at least one half *M. acuminata* that have been excellent seed parents are 'Red Baron', 'Black Beauty', and 'Yellow Lantern'. 'Black Beauty' × 'Gorgeous' is producing some attractive looking plants with reddish-bronze new growth.

It may be difficult to develop a magnolia that will bloom the entire summer, but *M. liliiflora* and *M. acuminata,* in addition to adding hardiness, also have an extended blooming period. *Magnolia liliiflora* hybrids such as 'March Till Frost', 'Ann', 'Betty', and 'Jane' can be late summer repeat bloomers if enhanced by sufficient rainfall. These need to be crossed with Yellow Bird', which is another repeat bloomer. Some of the New Zealand hybrids like 'Genie' and 'Cleopatra' also can be repeat bloomers so crossing them with 'Yellow Bird' could produce a long blooming magnolia with a good purple color. While 'Daybreak' and 'Rose Marie' will have a spring bloom of about a month, there generally is no repeat bloom on them. It may be possible to extend their spring bloom for an additional month by crossing them with some of the New Zealand hybrids.

While hardiness is my prime objective, a secondary goal is to develop narrowly fastigiate trees that will accommodate a compact landscape. Hybrids with a narrow growth habit include 'March Till Frost', 'Sunsprite', 'Sunspire', 'Black Beauty', and 'Daybreak'. I have made several crosses utilizing these hybrids, but it is too early to determine what the ultimate size of the resulting hybrids will be. Making crosses with some of the smaller-growing New Zealand hybrids like 'Genie' could also accomplish these goals. My most promising narrow growing hybrid thus far is a cross of 'Yellow Bird' × 'Apollo' with burgundy-red flowers. It bloomed as a young seedling, has many lateral flower buds characteristic of 'Yellow Bird', and an extending blooming period.

Another secondary goal is to develop a multi-tepaled magnolia with a good red/pink color. Crosses of *M.* × *loebneri* 'Leonard Messel' × *M.* × *loebneri* 'White Rose' have resulted in flowers with up to 24 tepals, but are a soft lavender-pink color. Quite likely there would not be enough pigmentation if the crosses are made within the species. If a cross of a diploid with a large number of tepals like *M.* × *loebneri* 'White Rose', *M.* × *loebneri* 'Encore', *M. stellata* × 'Pink Perfection', or *M.* × *loebneri* 'Wildcat' were made with pollen of a red-colored magnolia like 'Jurmag1' Black Tulip™ magnolia, 'Cleopatra', or 'Genie', the resulting hybrid may have good red/ pink pigmentation, but the dominance of the pollen parent with its higher chromosome count may not substantially increase the number of tepals. Backcrossing the resulting hybrids to the *M.* × *loebneri* selections may be necessary to increase the number of tepals.

The following are some of the named selections I have introduced:

Fig. 1. *Magnolia* 'Rose Marie'.

Magnolia 'Rose Marie', which is a cross of 'Pink Surprise' × 'Daybreak', is ¼ *M. acuminata* and ¼ *M. liliiflora* and is very late blooming (Fig. 1). *Magnolia* 'Rose Marie' starts blooming 1-2 weeks later than *M.* × *soulangeana* and can bloom for as long as a month; it and 'Daybreak' are my longest blooming magnolias in subgenus *Yulania*. 'Rose Marie' also has a nice columnar grow habit similar to 'Daybreak', a characteristic that is very desirable to landscapers. *Magnolia* 'Rose Marie' is very seed fertile and has been crossed with some of the New Zealand hybrids such as 'Genie', 'Cleopatra', 'Jurmag2' Felix Jury™ magnolia, and 'Ian's Red' with the goal of developing a hardy magnolia with the color intensity of *M. campbellii* subsp. *mollicomata* 'Lanarth'. Both 'Rose Marie' and 'Daybreak' also have been crossed with 'Gold Cup' with the goal of maintaining their vivid pink color and obtaining the flower form of 'Gold Cup' which has very thick, upright tepals.

Fig. 2. Magnolia 'Pink Charm'.

Magnolia 'Pink Charm' (Fig. 2) is a sister seedling of 'Rose Marie' with similar color but with a more lily formed flower. The tree is very fastigate and has a long blooming period similar to 'Rose Marie'.

Fig. 3. *Magnolia* 'Blushing Belle'.

Magnolia ‘Blushing Belle’ (Fig. 3) is a cross of ‘Yellow Bird’ × ‘Caerhays Belle’ has gorgeous pink flowers similar to ‘Caerhays Belle’, but with a bit less salmon color than its pollen parent. The deep pink exterior and lighter pink interior shows no traces of yellow. It is much hardier then ‘Caerhays Belle’ and has bloomed after -30°C. It also blooms later than ‘Caerhays Belle’ and thus avoids late spring frosts. The flowers are a bit smaller than ‘Caerhays Belle’, but maintain a better upright form. ‘Blushing Belle’ is seed sterile, but has good pollen fertility and has been crossed with ‘Rose Marie’, ‘Red Baron’ (*M. acuminata* × *M.* ‘Big Dude’), and others.

Fig. 4. *Magnolia* ‘Crescendo’.

Magnolia ‘Crescendo’ (Fig. 4) is a cross of ‘Yellow Lantern’ × ‘Big Dude’ with ‘Yellow Lantern’ being a cross of *M. acuminata* var. *subcordata* × *M.* × *soulangeana* ‘Alexandrina’ and ‘Big Dude’ being a cross of *M. sprengeri* var. *diva* × *M.* × *soulangeana* ‘Picture’. Huge pink flowers emerge from tiny flower buds to create a “crescendo” effect. *Magnolia* ‘Crescendo’ is a very free flowering, long blooming magnolia that was completely hardy at -30°C.

Fig. 5. *Magnolia* ‘Roseanne’.

Magnolia ‘Roseanne’ (Fig. 5) is a cross of *M. liliiflora* ‘O’Neill’ × *M. kobus* ‘Norman Gould’. This hybrid has six or seven tepals which are rich lavender pink on the outside and a lighter pink on the inside. The tepals are very broad and retain their upright form. *Magnolia* ‘Roseanne’ is a fertile tetraploid that is producing some excellent hybrids. The foliage is semi-glossy with a heavy texture.

Fig. 6. *Magnolia* ‘Royal Splendor’.

Magnolia 'Royal Splendor' (Fig. 6) is a cross of 'Pink Royalty × 'Daybreak' with 'Pink Royalty' being a cross of *M. acuminata* × *M.* 'Dark Diva'. The exterior of the nine pointed tepals is an intense reddish pink and the interior being a lighter pink. This hybrid bloomed as a 6-ft seedling and continues to be very floriferous with many lateral flower buds which prolong the bloom for as long as a month. This is the most intensely colored magnolia in my collection that glows like a beacon in the distance.

Fig. 7. *Magnolia* 'Sunset Swirl'.

Magnolia 'Sunset Swirl' is a cross of Pink Royalty × 'Daybreak'. A pink flowered magnolia that displays the gorgeous colors of a brilliant sunset. While the color of this magnolia is similar to that of 'Daybreak', the advantage of this magnolia is its excellent flower form which matures to a flat, pinwheel form with no floppiness.

Fig. 8. *Magnolia* 'Cotton Candy'.

Magnolia 'Cotton Candy' (Fig. 8) is a cross of 'Red Baron' × 'Blushing Belle'. The huge flowers have nine broad tepals that are a medium pink on both the exterior and the interior and show no traces of green or purple. With its genetic background being 7/16 *M. acuminata*, it is a very hardy "campbellii type" magnolia for colder climates.

Fig. 9. *Magnolia* 'Burgundy Spire'.

Magnolia 'Burgundy Spire' (Fig. 9) is a cross of 'Yellow Bird' × 'Apollo'. I was impressed with its very narrow growth habit as a young seedling and thrilled to see it bloom with a clear burgundy exterior and a cream interior. The nine tepals remain upright and do not flop as the flowers age. Because of its abundance of lateral flower buds, it remains in bloom for several weeks. This is a very desirable magnolia for limited garden space.

I am also doing extensive hybridizing in subgenus *Magnolia* by crossing *M. grandiflora*, *M. virginiana*, *M. tripetala*, *M. obovata*, and *M. sieboldii* with red/pink flowering magnolias from Section *Manglietia* with the goal of developing red/pink flowers in these species.

In conclusion, much work needs to be done and I am happy to see other magnolia enthusiasts becoming actively involved in magnolia hybridizing. However, we must be aware that crossing two outstanding cultivars will not always result in a hybrid with the best attributes of both parents, and many disappointing hybrids can result.

Currently I have nearly a thousand hybrids planted out for future evaluation and have been sharing seed with friends throughout the world with the hope that many outstanding cultivars will be introduced in the future.

Grafting Rhododendron on pH Neutral Understocks©

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Recently, I was vacationing in the Smokey Mountains and the mountains around Asheville, North Carolina. I was amazed by the vigorous growth of the wild rhododendron. The plants were small trees and were best pruned from the hiking paths not with propagation pruners but with bushhogs. Unfortunately many parts of North America lack a gardening soil even remotely close to the well-drained acidic organic mountain soils that allow these plants to thrive; hence the origin of this journey.

Before I begin to discuss grafting of rhododendron it might be best to introduce our company. Decker Nursery was founded in 1921 by my Grandfather, Paul Offenberg. He was a professionally trained horticulturalist from Holland and brought with him, along with many other European immigrants, the propagation skills necessary to found the Paul Offenberg Nursery. Through the Great Depression, World War II, and the emergence of horticulture in the post war era, Offenberg Nursery grew into another generation with Bernard Decker, Paul's son-in-law, as President. In 1981 the Offenberg Nursery relocated, reorganized, and changed its name to Decker Nursery, Inc.

Decker Nursery began to expand into wholesale production for the regional Ohio market. As propagation began to expand to supply liners to the trade, the Landscape Department was closed. Decker Nursery currently produces plants on 132 acres in Groveport, Ohio. It has field production for B&B trees and evergreens, 30 acres of container production, and about 5 acres of propagation and liner production facilities. The finished stock side of production at the Decker Nursery is primarily shipped to a regional Midwest market. The propagation department is national and is currently shipping to 38 states and Canada.

In the propagation department we produce in each year about a million hardwood and softwood cuttings. We root licensed plants in programs such as Proven Winners®, PlantHaven®, LCN Introductions®, Plants Nouveau®, UpShoot LLC®, and others. We also root non-licensed taxa. In addition to rooted cuttings, we graft approximately 120,000 plants each year. These grafted plants include *Acer palmatum*, *Ginkgo*, *Cornus*, *Aesculus*, *Fagus*, *Juniperus*, *Chamaecyparis*, *Pinus*, *Picea*, and last but not least, *Rhododendron*. The foundation has been laid and now back to the rhododendron journey.

We were approached in 2011 by Linda Guy of Plants Nouveau to ask if we would be interested in grafting hardy, proven North American cultivars of rhododendron onto a new licensed selection of *Rhododendron* understock that was developed in Germany. This is when we became introduced to INKARHO® rhododendrons.

The name INKARHO, according to the INKARHO website <www.inkarho.de> , is short for INter-essengemeinschatt KAlktoleranter RHOdo-dendron. This translates as "lime-tolerant rhododendron." The history of these plants is that they were developed by a group of 15 German nurseries. In 1980 with the support of these nurseries, the German Federal Institute for Ornamental Plant Breeding (IZZ) began the 25 years of breeding and testing to develop rhododendrons with strong root vigor and tolerance to high pH soils. They believe after testing throughout Germany and other countries in Europe that with the INKARHO plants they have achieved this goal.

In addition to being alkaline tolerant understock, the INKARHO understocks are, according to the German Breeding Institute, able to instill a higher level of vigor in all grafted plants. The claim is that under all conditions, even normal native acidic soils, the understocks result in a more vigorous plant. It will take many years of testing to determine if this claim proves true in the USA.

In information collected from Linda Guy, it is believed that the INKARHO line was introduced into the USA through Dave Weil of Varieties International LLC based in Dundee Oregon. Dave arranged for the rhododendron understocks to be sent to Dieringer, a rhododendron grower in Oregon. The Dieringer owners were working on perfecting a grafting technique when the business went bankrupt shortly after the year 2000. At this time, Tom Demaline, President of Willoway Nurseries, stepped in to try and rescue the pH Neutral Rhododendron Program.

The rhododendron grafting was picked up at Willoway. Through trial and error they determined that of all the numbered clone understocks, INKARHO #37 was the strongest grower and best suited for production in the USA. The propagation department at Willoway was given the task of grafting the plants with cultivars well known in North America. Since Willoway does little in-house grafting, the program has moved along with mixed results on the grafting success. It did, however, yield enough plants to allow Willoway to begin to introduce the INKARHO understock plants into the North American market.

The INKARHO #37 understock is a plant worthy of note as is. It has a lovely soft pink flower and is currently being sold at Willoway Nursery as Rhododendron INKARHO ‘Lakeview Pink’. The INKARHO line of rhododendron at Willoway Nurseries is still being evaluated for customer acceptance. The line has been in Germany for several years but is still in need of evaluation in the USA.

In 2011-2012 Decker Nursery was supplied 100 INKARHO #37 understocks for grafting trial. One plant was dead on arrival, however, we were able to return 96 live grafts to Willoway Nursery the following summer. It was determined at Decker Nursery to do a more substantial trial program the following year.

In the 2012-2013 winter season we wanted to graft about 2,000 plants. Due to rooting problems Willoway Nursery was unable to supply INKARHO #37 understocks. As we were not experienced in the rooting of rhododendron cuttings, we solicited protocol advice from IPPS Eastern Region members at the 2011 October Annual Meeting in Pennsylvania. We combined valuable information from Shelby Ruffino of Prides Corner Nursery and Dave Geary of Willoway Nursery to come up with the following protocol for rooting rhododendron INKARHO #37 cuttings at Decker Nursery.

Rhododendron cutting protocol:

- Hortus dip 8000 ppm
- Wound: One side, vegetable peeler, shallow
- Overspray Hortus 2,000 ppm weekly
- Shade 50% on the house
- Mist as required (4 sec every 10-30 min., target 85% relative humidity)
- Flats under trays for extra drainage
- Medium: peat, coir, perlite (1 : 2 : 4.5, by vol.)
- Cuttings stuck in late October/early November
- Bottom heat 68-70°F

We stuck the cuttings shortly after the IPPS Eastern Region meeting. The cutting wood arrived and we made the decision to stick the larger cuttings in 4-in. pots for this season’s grafting and the smaller cuttings were stuck in 2.5-in. plugs for the 2014 season. The 4,000 cuttings stuck rooted at nearly 100%. The larger cuttings in 4-in. pots were ready for grafting in mid-February.

It should be noted that Shelby Ruffino told me that he suspected the cuttings might be rooted satisfactorily by February for grafting. This off-the-cuff comment trimmed 1 year off the production cycle and dramatically reduced the cost of the grafts. (Talk about the value of the IPPS motto: to seek and share!)

We prepared a grafting tent placed directly on the bottom heat concrete floor. Scions of the following rhododendron cultivars were collected from Willoway Nursery:

- ‘Nova Zembla’
- ‘Roseum Elegans’
- ‘Boursalt’
- ‘Chionoides’
- ‘Lee’s Dark Purple’

The scions were stripped of any flower buds and leaves were trimmed similar to the method for making cuttings. A short side veneer graft was made on the understock and a matching cut on the scion. It is interesting to note that in the 2011-2012 first grafting experiment the understocks were 1 year old and the wood was very difficult and brittle to cut. In the 2012-2013 season we were grafting on 1-year-old wood of cuttings that were only 2-3 months old. The wood was soft and easy to cut thus yielding better graft fits. The fresh grafts were mulched with aerated moist peat moss and placed in the grafting tent on bottom heat floors. After about 6-7 weeks the grafts were healed and showing good callous growth and the tent was gradually removed. The understocks flushed growth first. When the understock foliage began to be a shade threat, the understocks growths were removed. This resulted in a quick flush of growth from the swollen budded scions. It should be noted that some of the grafting rubber bands were also removed from some grafts at the time of understock growth removal. I noticed that some of the graft unions "shattered" from the shock of the cut and we quickly discontinued rubber strip removal until a later date. The shattered grafts were the only substantial loss of any grafts in the entire crop.

The grafts continued to flourish and grow and a large number of assortment trays of 15 plants were given to existing liner customers that expressed an interest in trialing the INKARHO #37 understock rhododendron grafts. The remaining grafts will be up potted in the spring of 2014 to begin to develop larger plants for evaluation and propagation stock. The smaller cuttings of INKARHO #37 that were intended to be used as understocks for the 2013-2014 grafting crop were instead potted into 1-gal containers and will be both stock plants for cuttings and trial plants "as is" for the Willoway cultivar rhododendron 'Lakeview Pink'.

In conclusion it is clear that the pH neutral rhododendron INKARO #37 program in North America is in its infancy. The following facts though are beginning to be clear:

- The grafting of this plant is not difficult and can clearly be a commercial success.
- It is unproven if the INKARHO #37 understock will be a success in the North American environment. I have seen many successful plants from Europe that failed in the North American climate. Rhododendrons have been enough of a challenge to the American gardener to add another failure to the list.
- Tom Demaline has stated that the message must be sent that pH neutral does not mean "poorly drained soils". Soil drainage and moist organic soils are the key. Just like other rhododendrons, wet feet will lead to decline.
- The INKARHO rhododendrons also have selections of "fragrant hedge cultivars." These plants should also be trialed in North America to determine if they have a place in the landscape. They do not require grafting.

Progress in *Carpinus caroliniana* Propagation and Selection©

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In 2001, in Lexington, Kentucky I presented a paper for the IPPS — Eastern Region entitled, "*Carpinus caroliniana* Production at Johnson's Nursery, Inc.". I would like to give you a brief review of that work and update you on the new developments I have encountered in the last 12 years.

PROPAGATION AND PRODUCTION

Seedling Production

Over the past 32 years, through Johnson's Nursery in Menomonee Falls , Wisconsin, I have worked on developing a seedling strain of *C. caroliniana* that has a high percentages of seedlings (70% +) with brilliant orange-red fall color for the Upper Midwestern part of the country. It has been called *C. caroliniana* J.N. Strain. This strain has incredible vigor when compared to seedling plants grown from wild collected seed from our area. Because of this, production times for this species have been significantly decreased at our nursery. It takes 2 years less to finish a 5 ft shrub form B&B plant than it did when we used wild collected seed from what we had suspected were inbred ecotypes in the mid-80s (Figs. 1 and 2).

In recent years, we have modified our production practices to be even more selective of our seed sources and to cull plants based on fall color performance. For instance, seed is picked at the time of fall coloration so that we can identify the blocks with the highest percentages of orange-red colored plants. We review all the blocks in the nursery before proceeding to pick. Once we have the best blocks identified we pick from the most colorful individuals that have good seed (Fig. 3). Then we grow the seedlings in an outside seedbed for a year. We dig and grade the plants in late fall, saving the best grades for our field production. They are typically 6-12 in., 1-0 seedlings, though we do usually get a small percentage of 12-18 in. plants. Plants under 6 in. in height are culled.

Fig. 1. *Carpinus caroliniana* seedlings at Johnson's Nursery in 1984 – a few have red fall color.

Fig. 2. *Carpinus caroliniana* J.N. Strain at Johnson's Nursery in 2001 – improved percentage of individuals with red fall color.

Fig. 3. *Carpinus caroliniana* J.N. Strain at Johnson's Nursery in 2008 – continued improvement in percentage of individuals with red fall color.

The seedlings are lined out in transplant rows for a year. In autumn, they are evaluated for fall color and any non-orange-red, fall-colored plants are destroyed. They are dug, graded, root pruned, and bundled in the late fall. In spring the plants are lined out at one foot apart in rows 5 ft apart. Again, only the top of the grade is allowed to go to the field. These are grown in this location for 2 years. Most plants will grow to a 18-30 in. in height in this time frame. Again, any plants not colored orange-red in the fall are culled.

These liners are spring dug bareroot and lined out in rows 10 ft apart and the plants spaced 5 ft apart. In year 3 at this location, we expect to begin selling 4 to 5 ft, shrub form, B&B plants from the block. The rest of the block should be mostly gone by the end of year 5 if the market is healthy.

Clonal Selection and Propagation

Cultivar selection of *C. caroliniana* and their propagation is a relatively new endeavor in our industry. Few cultivars have been selected from this species and of those, most are not adaptable to Southern Wisconsin. The two most commonly available cultivars in commerce, 'WFS-KW6', Native Flame® and 'CCSQU', Palisades® musclewoods, have not proven to be reliably hardy in Wisconsin. I suspect they were selected from provenances much further south than Wisconsin. It was for this reason as well as the availability of large populations of seedlings to select from, that cultivars derived from northern seed provenances were selected at Johnson's Nursery. The two that have been released to date are: *C. caroliniana* 'J.N. Globe', Ball O' Fire™ musclewood (Fig. 4) and *C. caroliniana* 'J.N. Upright', Firespire™ musclewood and (Fig. 5). As can be inferred from the names of these *C. caroliniana* clones, they were selected for their unique forms and wonderful orange-red fall colors.

Fig. 4. *Carpinus caroliniana* 'J.N. Globe', Ball O' Fire™ musclewood.

Fig. 5. *Carpinus caroliniana* 'J.N. Upright', Firespire™ musclewood.

Clonal propagation of *Carpinus caroliniana* has not been readily documented. The species is said to be able to be rooted from softwood cuttings but is difficult. I can attest to that as being true. Of the hundreds of cuttings that I have stuck at various times of the year over the last 25 years or so, I have one plant to show for it. I know of numerous nurseries in Oregon that produce *Carpinus caroliniana* clones by grafting in the winter with the use of a hot callus pipe. A tissue culture lab is working on the micro-propagation of *Carpinus caroliniana* but has not succeeded as yet.

Grafting Process

I would like to explain a grafting process that I am perfecting after working on it for the last 15 years or so. It is a method of side-veneer grafting cultivars of *Carpinus caroliniana* in summer in an unheated polyhouse under mist (Fig. 6).

Fig. 6. Newly completed graft.

The keys to success with this method are the timing of when the grafts are done, mid-summer, and the condition of the scion wood and understock. They must be very vigorous or success is unlikely. For understock, I pot 1-0 bareroot seedlings that are typically 6-12 in. tall with a caliper size of 1/8-3/16 in. They go into a #1 container. By summer grafting time, mid-July, these plants grow to become ¼” to 5/16 in.-caliper plants, ideal for grafting. Scions are gathered from plants grafted in the previous three years. These young, vigorous growing plants will have current season’s growing shoots from 18 to 30 in. in length with stem calipers up to ¼ in. in diameter. The scions should be lignified at the base. If they are too green they rot readily.

The grafting itself is rather typical. I use a cut that is about one inch long and perfectly flat on one side with a wedge at the base in which to place the scion. I make the same matching cut on the scion and line the cambiums up on one side. When preparing the scion, I use a 6-in. stick from the bottom of the vigorous shoots described earlier. I leave 3 or 4 leaves on the scions and may cut some of the leaves in half if they are relatively big. The grafts are tied with a light-gauge budding rubber. The completed grafts are taken to an unheated polyhouse covered with white 4-mil overwintering poly and 55% Saran shadecloth. They are placed straight up in a bed of sand with the pots and unions buried. The plants are pot to pot in rows that are 15 in. apart.

I make sure the pots are thoroughly watered before plunging them in the sand. The grafts are misted for 12 s about every 15 min on a typical sunny summer day. The house is rarely vented. Temperatures in the graft house can go to 110°F. Once it gets hotter than that I may vent the house by opening doors and increasing the mist frequency, About every 10 days I turn the mist on for about 4 h to thoroughly water the grafts. After about 7-8 weeks the grafts are healed and the mist is gradually cut back and the doors of the polyhouse are opened.

The plants are allowed to go into dormancy naturally outside before they are overwintered in an insulated unheated building for the winter. In late March, they are pulled from the building and placed in an outdoor growing area. Once new growth commences, they are cut-back and re-potted into larger containers for growing on. Depending on the variety grafted, they will typically grow to 3 to 4-ft tall plants the first season after grafting. I usually do little pruning because I want to save the vigorous wood for the next season's scions. I suspect if the plants were to be pruned earlier in the season taller plants could be developed in one season.

The grafted plants are upshifted to a #5 container at the beginning of the 2nd year after grafting. By the end of this growing season the *Carpinus* will typically be 4-6-ft branched plants.

My most recent cultivar selection work with *Carpinus caroliniana* has been focused on faster growing cultivars with orange–red fall color as well as fastigiate, spreading and pendulous forms. I hope the improvements that I have made in selecting superior cultivars of *C. caroliniana* and in gaining a better understanding of their propagation and production will make this species much more commercially viable than it has been in the past.

More Cheese Please©

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At Mckay Nursery we use a polycarbonate greenhouse to root some of our more difficult-to-root softwood cuttings. We root them in square flats in a peat and perlite medium. We were having problems keeping the cuttings turgid while maximizing our mist interval. Instead of increasing the frequency of misting, which could lead to increased disease, we are using cheesecloth.

In the past cheesecloth has been used mostly for shading and moisture distribution. Our use of cheesecloth distributes moisture evenly and also brings the moisture to the surface of the leaves and stem. Our use of cheese cloth differs from the use in the past because we are laying the cloth directly on the cuttings not using a structure to support the cloth above the cuttings.

The cheesecloth is used to create a moisture-rich microclimate around our softwood cuttings (Fig. 1). To reduce transpiration and decrease solar exposure we drape cheesecloth, which gets moistened by the mist, over the cuttings. Because we drape our flats in cheesecloth the moisture weighs down the cheesecloth and helps it form to the surface of the cutting. We leave it on until callus formation or roots start to show, depending on the plant. This allows us to extend the mist interval and allows for more air exchange in the greenhouse.

We have seen an increase in rooting percentage in many plants using this method. Along with increased rooting success we are able to root softwoods in a structure while it is simultaneously growing other crop. This method is much more inexpensive then modifying or renovating our existing mist system. With this method we are able to use our entire bench space and reduce the amount of mist the plants are receiving.

Fig. 1. Cheesecloth covering the cuttings.

Upping Our Labor Game©

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For the past 5 years, Spring Meadow Nursery has been actively seeking and implementing more efficient ways to work. We have made changes throughout our production departments, but most of what I am going to talk about today focuses on the propagation department which includes making and sticking cuttings and transplanting.

Figure 1 shows one person sticking cuttings in their own flat, a method that we used for 20 years (pre-lean flow). Following training in lean flow methods in 2009, we found that by changing to progressive or an assembly-line sticking method, we were able to increase productivity by 15% (Fig. 2). This method uses three people sticking flats. The first person removes the medium-filled flat from the upper conveyor and sticks approximately one-third of the cuttings. The second person sticks approximately one-third of the cuttings. The third person will finish sticking what is needed and place a plant label on the flat and move the finished flat to the lower conveyor. This method works very well when training new workers or trying to bring slower workers up to speed by placing the slower person in the middle so that they are pushed by the worker on their right and left sides.

Fig. 1. Each person sticking cuttings in their own flats.

Fig. 2. Progressive sticking group of three people.

After 3 years of progressively sticking cuttings, we topped out any further labor savings. To continue the labor savings process, we purchased an AgriNomix indexed flat conveyor this season which automatically advances a medium-filled flat when one is removed from the conveyor (Fig. 3). So far, the indexing conveyor has boosted our productivity 18%.

Fig. 3. AgriNomix indexed flat conveyor system.

Table 1 illustrates one example, sticking 32 cell trays, of a 63% efficiency gain that we have achieved over the past 5 years. This is a group rate and includes the person running the flat filler, off-loading the flats from the conveyor to the carts and hauling carts to the greenhouse.

Table 1. Illustrates the gain achieved over the past 5 years.

	2008	2009 Introduced Lean-Flow Techniques	2010	2011	2012	2013 Introduced indexed tray feeding	Total Productivity Gain So Far (5 years)
Flats per man hour (32-cell tray)	24	27	30	34	33	39	63%

A lean flow technique that we use to keep workers informed of their output is shown in Figure 4. A white board with hourly production updates is maintained by the crew leaders. On this day, as of 12:30 PM, the transplanting and sticking crews were well above their expected rates, 130 and 159% respectively. Crews that produce above the expected rates are paid a performance based incentive every 2 weeks.

A TTA USA mechanical transplanter (Fig. 5) was installed in June 2013, to increase the efficiency of transplanting a 72 plug into a quart pot. So far, we have been able to triple the manual transplant rate, and expect further productivity increases in 2014, as our workers become fully trained.

Fig. 4. Hourly production output.

Fig. 5. TTA USA mechanical transplant line.

The AgriNomix tray destacker and pot loader (Fig. 6) which is on the transplant line was also added this season. This machine has eliminated one worker; however, it has been far from trouble-free. The main problem has been static of the pots which occasionally require a worker to manually place the pot in the tray. We are working with the plastic manufacturer and AgriNomix to correct the problem.

We have 20 acres of greenhouses containing rapidly growing young plant material which require regular pruning to encourage branching and to keep plants within their size specification. Figure 7 shows the hedge pruner method which was used for many years, requiring a worker to bend over holding a 40-inch hedge trimmer all day. The clippings are swept up by another worker. The rate for manual trimming and clean-up is 600 flats/man hour.

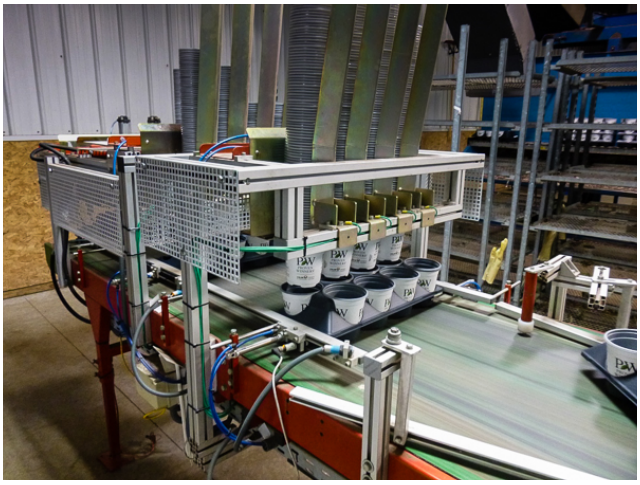

Fig. 6. AgriNomix tray destacker and pot loader.

Fig. 7. Trimming liners with a hedge pruner.

Fig. 8. Mechanical trimmer.

Two years ago we contracted for the construction of the mechanical bed-width trimmer (Fig. 8) that runs on rails on both sides of the bay. It has the ability to be raised and move over plants that do not need trimming. The clippings are swept to a conveyor at the back of the trimmer and deposited to the sidewalk for easy clean-up. The rate using the trimmer is more than 10 times that of the worker with the hedge pruner: 6000-8000 flats/man hour.

By making our facility more efficient, it has been a win-win for both management and staff.

Incentive Driven Tasks at Prides Corner Farms©

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The challenge for a large wholesale nursery with a limited growing area is to perform all the necessary tasks required to produce the best quality plants in the timeliest manner.

INCENTIVE DRIVEN TASKS AT PRIDES CORNER FARMES

- Fertilizing: Measured per spoon application with 4 to 5 individuals in a fertilizing crew.
- Potting: Measured in number of plants potted per day with approximately 12 to 14 people in a potting crew.
- Covering houses in the fall: Measured in amount linear feet covered per day; approximately 12 individuals in a covering crew.
- Spacing: Measured in number of plants spaced per day, made up of 3 person crews.
- Consolidation: Measured in number of plants put away each day, made up of 3 person crews.

Space at Prides Corner Farms is always at a premium and requires careful planning so that everything gets done as quickly as possible in a way that the plants are never compromised.

Example of How the Spacing Incentive Works

Because of our limited space plants are moved often. Plants are moved when they are first potted, usually pot to pot the 1st year, than spaced out the 2nd year followed by consolidating these same plants in the fall so that they can be covered prior to winter. All of these tasks require that the job is done quickly but professionally. This is where group incentives play a major role to accomplish all that needs to be done.

In the spring, usually late April, plants are spaced out in the nursery (Fig. 1). It is necessary to wait until this time because space needs to, first be made, by shipping saleable plant material. Three-person crews will space out these plants on an incentive driven basis. Over the years a “Reasonable Expectation” (R.E.) for this and all incentive driven tasks was developed. The crews must space out a minimum required amount of plant material before they break even. From this point on any plant that they space out is accumulated towards their incentive. When tabulated any incentive money earned is split 3-ways so that all 3 crew members earn an equal share. The formula for spacing is as follows:

Number of employees × total hours worked × a set rate

On the other side of the equation is:

Number of plants spaced × amount paid per plant.

Different rates are paid depending on the size of the container spaced and the distance those plants are moved. The crew leader has a field sheet that he or she is required to fill in at the end of each day. The crew leader inserts into the proper column the following:

- Number of plants moved,
- Hours that were worked spacing these plants,
- Names of the employees doing the work.

The following is an example of how the formula might work: If three employees worked 8 h and spaced out 4,000 #2 containers and those containers paid $0.066 each to move, the formula would look like this.

3 × 8 × $7.75 (set rate) - 4,000 × 0.066 = $186.00 - $264.00 = $78.00

In this case the three individuals made a positive $78.00 or $26.00 each for that day’s work. If the total was a negative, or they did not at least make $186.00, the formula would produce a “0” meaning that no incentive would get paid for that day’s work.

When plants are consolidated in the fall the formula would look very similar except that the rate that is paid per plant would change (Fig. 2).

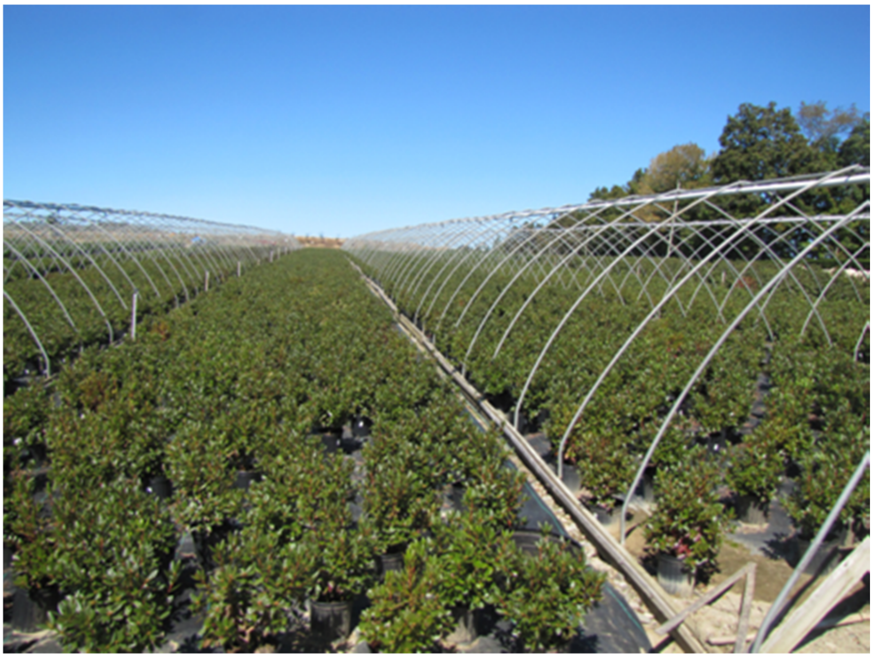

Fig. 1. Spaced out plants.

Fig. 2. Consolidated plants at the end of the growing season.

Example of How the Polyhouses Are Covered in the Fall and Incentive

Covering houses in the fall is also on a group incentive driven basis. Prides Corner Farms has to cover in excess of 60-linear miles of houses with over-wintering film each and every year. Our goal is to always have these houses covered by Thanksgiving. We insist on this because the weather after this date can be often unpredictable. The formula is the same as plant movement except instead of number of plants moved it would consist of number of linear feet of houses covered. Again, there would be a R.E. that has to be met before the group would begin to make a positive incentive.

Example of How the Fertilizing Incentive Works

Fertilizing plant material is based on number of measured scoops applied each day by the total crew.

(Number of people × hours worked × pre-set rate) – (number of plants fertilized × rate per plant)

Example: Three people worked 8 h and fertilized 25,000 plants at $0.01 per scoop

$$(3 \times 8 \times \$7.75) - (25{,}000 \times 0.01)$$
$$(\$186) - (\$250) = \$64.00$$

The three employees would split $64.00 for that day or $21.33 each.

Example for Potting

Potting plant material is based on the number of plants potted. Variables to this would be size of the plant, (liner, bare-root plant, step-up) as well as the container size the plants are going into.

WHEN STARTING AN INCENTIVE PROGRAM, WHAT NEEDS TO BE CONSIDERED?

The following factors need to be taken into consideration when developing a group incentive program:

1) It needs to be long term. You are encouraging individuals to work at a high degree of productivity over a long period of time. Incentives are geared towards jobs that are repetitious, long lasting and possibly physically demanding. Incentives help to maintain that level of productivity over a period of time.
2) Needs to be a win-win for both the employee and the company . Reasonable expectations (R.E.) are critical for determining the minimum requirement expected of any employee. By determining these R.E.'s a better incentive program can be developed. The incentives can't be so demanding that it is almost impossible for the employees to make any extra money and can actually create a disincentive, which could cause the employees to work less productively. If the incentives are balanced it creates a positive work environment for the employees and allows the employer to hire less people to do the work.
3) Needs to be self-policing. Any individual in a crew who does not want to make an effort will hold the others back from making this extra money. Self-policing of the crews will either weed out poor performers or encourage those who are not motivated to pick up the pace.
4) Quality can't suffer. There is always an inherent risk when group incentives are offered for the overall quality to suffer. Productivity is monitored and work is inspected by team leaders overseeing the work. If the job is not up to standard the crew is made to re-do the work, which will negate any incentive they may or may not have made. All field sheets need to be signed off by a "senior team leader" before being turned in and the final copies are inspected again to make sure that there was no data entry mistakes made during this process.

CONCLUSION

At Prides Corner Farms we have found that group incentives are a valuable tool to help get large tasks done quickly and professionally. When monitored and critiqued they offer a way to increase productivity, hire less people and offer a monetary reward for those who maintain a high level of production. If anyone would like to have more information regarding our group incentives at Prides Corner Farms, please contact us.

Light Emitting Diodes Lights Make Rooting Micro-Cutting Lilacs Easier and Safer©

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INTRODUCTION

Minnesota in the winter is not the ideal place to try to propagate woody ornamental cuttings. Cold temperatures and low light conditions make rooting cuttings a real challenge. So when Bailey Nurseries (www.baileynursery.com) in St. Paul, began reading about how European growers were using light emitting diodes (LED) lights to root cuttings it piqued our interest.

In 2011, we worked with Philips and Hort Americas (our supplier and technical support — the contact info is Chris Higgins at chiggins@hortamericas.com) to design a separate propagation room not in the greenhouses to trial the LED lights.

OUR START IN 2011 WITH LIGHT EMITTING DIODES LIGHTS

We started our trial in Feb. 2011 and ran a range of crops under the lights. We used three Cannon carts tied together side by side to form one large shelf that can hold up to 15 trays. The trial was conducted in a corner of the germination room. The germination chamber was the perfect location for the trial. It is located inside a production building, provides a constant 70°F temperature, has misting capacity (fog nozzles in the ceiling), and electricity is easily available. The propagation area was partitioned with black and white plastic to avoid light contamination from the fluorescent lights (used for germination). The trial area had no other lights, other than the "GreenPower LED production modules" made of 75% deep red and 25% blue lights that were located about 16 in. away from the cuttings. The modules are 5 ft long, which matches the size of the Cannon carts.

A range of cuttings were taken from plants in the greenhouses, including *Spiraea*, *Celastrus*, *Physocarpus*, and *Hydrangea* to name a few. We also included in the trial 900 microcutting lilacs. The greenhouse cuttings were stuck in 38-cell plastic trays (standard 11 in. × 21 in. size). The tissue cultured lilacs (microcuttings) were grown in three 288 trays. The medium used was Preforma®. The cuttings were sprayed with IBA to help initiate rooting, except for the tissue cultured lilacs.

- The fogging system fills the entire room with fog, and for this reason, there is no hand misting necessary. The fog kept the cuttings turgid.
- The fluorescent tubes maintain the room at a constant air temperature of 75°F.
- The LED lights generate some heat and provide the light spectrum that is required to sustain plant growth.

For these reasons, The Preforma plugs remain moist, the cuttings remained turgid, the temperature and light source is constant, and the cuttings never get stressed. There is little to no grower care required under these growing conditions, but the cuttings still receive a weekly preventative fungicide treatment.

OUR CURRENT SETUP: GREENPOWER LED PRODUCTION MODULES

Based on the 2011 successful results in the chamber, we purchased more GreenPower LED production modules. We are now able to move carts in and out of the chamber with total ease. We have six carts, with five layers per cart for a total of 150 flats. This is the only space currently allocated to LED multi-layer production where we now think in number of plants per cubic foot instead of square foot.

During the 2012 winter we rooted 16,000 lilac microcuttings or 25% of the French lilacs (*Syringa vulgaris*) schedule. The rest of the schedule (48,000 cuttings) was rooted in our greenhouses. In 2013, we rooted 66,000 microcutting lilacs, the full schedule.

Our normal greenhouse conditions require the presence of a grower every 20 min. These tissue culture lilacs are rooted inside several tents in one of our greenhouses. The tents are used to create a microclimate that is easier to control than trying to control an entire greenhouse. Depending on the level of sun intensity, on how much moisture is in the air, on how often the heaters are running, the grower in charge has to adjust the mist cycle, the amount of shade, and how much venting to match the outside growing conditions constantly. In the chamber, there is none of that.

Table 1. Lilac 2013 yield summary.

2013 micro-cutting lilacs	Cuttings received (no.)	Rooted cuttings (no.)	Cuttings lost during rooting no. (%)	2013 LED chamber	7 years average
First shipment (1/8/13)					
Common White	19872	18536	1336 (6.72)[x]	93.28	87.5
Madame Lemoine	4032	3864	168 (4.17)	95.83	71.3
Wonderblue	2016	1904	112 (5.56)	94.44	82.8
Second shipment (1/30/13)					
Andenken an Ludwig Späth[z]	2880	2594	286 (9.93)	90.07	66.8
Miss Ellen Willmott	1152	1026	126 (10.94)	89.06	74.75
Sensation	11808	11400	408 (3.46)	96.54	79.71
Third shipment (2/19/13)					
Yankee Doodle[y]	6048	3116	2932 (48.48)	51.52	63.4
Sensation	10368	9760	608 (5.86)	94.14	79.71
Albert F. Holden	2016	1444	572 (28.37)	71.63	61.4
Krasavitsa Moskvy[z]	4896	4256	640 (13.07)	86.93	74.16
President Lincoln	1100	1100	0 (0)	100.00	71.66
Total	66188	59000	7188 (10.86)	89.14	73.92

[x]The number in parenthesis indicates the loss percentage.

[y]'Yankee Doodle' suffered some shipping damages. That is why this cultivar is the only one that reads a lower percentage under LED compared to the 7-year average.

[z]'Andenken an Ludwig Späth', syn. 'Ludwig Spaeth'; 'Krasavitsa Moskvy', syn. 'Beauty of Moscow'.

CROP GUIDELINES FOR THE CHAMBER

The grower responsible for the crop will check the fog level, how wet the cuttings are, and check the cycle on the clock. This only takes a few minutes 4 or 5 times a day.

The light regiment is 16 h on and 8 h off. They start at 4 AM and they go off at 8 PM. The mist water is treated with a water softener to remove the impurities (calcium deposits) that could accumulate on the diodes. It is important to keep them as clean as possible or the light quality and intensity will be reduced. The mist cycle is also on a timer. When the pegs on the timers are "out" the mist is on. If the pegs are "in" the fog is off. This gives us the ability to control the amount of water that goes on the cuttings. Early on, the mist will be close to live. As the cuttings age, they receive less and less water. The first roots are seen after a few days. At 10 days most cuttings will show some roots. At 2 weeks, some roots will be at the bottom of the cell and coming out of the drain holes. Most of the cuttings have roots. This is also the time when we fertilize them. The lilacs are fertilized by dipping the trays in a 50 ppm solution of liquid fertilizer. At 3 weeks they are ready to leave the chamber. It is recommended to keep them for a few more days to let the stragglers catch up. Once in the greenhouse, they are fertilized again, and will be transplanted in the sand soon after.

THE 2013 ECONOMICAL ANALYSIS

- We purchased 66,200 cuttings.
- We planted 59,000 rooted cuttings in our greenhouses.
- The yield percentage was 89% under LED.
- The 7-year yield average is 74% in our greenhouses.
- The cost of a cutting is about $0.70.

Table 1. Analysis.

66,200 × 89% = 58,918 rooted cuttings or 7,282 lost cuttings at $0.70 = $5,000 lost
66,200 × 74% = 49,000 rooted cuttings or 17,212 lost cuttings at $0.70 = $12,000 lost
The difference, $12,000 - $5,000 = $7,000 saved when using LED versus the greenhouse

Because of the increased yield under LED lights, the estimated losses can be reduced by 10,000 cuttings or by $7,000. Running 60 production modules for 16 h per day cost less than $3 per day.

SUMMARIZED LIST OF BENEFITS FROM THIS PROPAGATION METHOD

- Increased yield,
- Reduced plant loss,
- Increased plant quality,
- Reduced crop timing,
- Reduced and simplified grower care,
- Reduced greenhouse cost, heat, and maintenance,
- Free greenhouse space,
- Avoid greenhouse construction and make better use of current space,
- Simplify and streamline production,
- Accelerate propagation,
- And make propagating possible at any time of the year as long as a cutting source is available.

Clonal Propagation of Oak Hybrids Using a Modified Layering Technique©

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Oak (*Quercus*) hybrids were created using over 40 diverse parent species. The developed hybrids were used as stock plants and asexually propagated annually over 4 years. This was done to measure the effectiveness of a modified stool bed layering technique on diverse members of the oak genus, and this study is part of a long-term project to select superior urban-tolerant oak hybrids for introduction as named cultivars into the nursery industry. The number of shoots produced by a stock plant each year and the probability for those shoots to root were found to vary between different maternal parent species. Results suggest the shoots of the hybrids that are the progeny of rhizomatous shrub *Quercus* spp. are more likely to develop roots when propagated using the described technique. This article also identifies and describes in detail a reliable technique to clone oaks.

INTRODUCTION

Oaks (*Quercus* spp.) are noted for their sexual infidelity, and natural hybrids commonly occur wherever two interfertile species from the same subgenera grow near each other (Sternberg, 2000). This tendency to hybridize is a useful trait that may be utilized by plant breeders to create hybrids with desirable characteristics such as attractive fall color, tolerance to site conditions, and hybrid vigor. Increasingly, a number of purported hybrid oak selections are becoming available in the nursery industry (JFSchmidt, n.d.; Dirr, 2010).

Until recent years, relatively few selections of oaks have been made due to the difficulty involved in asexually propagating members of this genus by conventional methods. Oaks are notoriously difficult to bud or graft successfully, which compounds the problem of producing superior selections. Recently, a modified layering technique that incorporates juvenile shoots, etiolation, and treatment with indolebutyric acid (IBA) has shown promise in the asexual propagation of *Quercus* species (Amissah and Bassuk, 2009) (Hawver and Bassuk, 2000). A study examining the usefulness of this propagation method on numerous hybrid oaks was conducted at the research farms of Cornell University, in Ithaca, New York. The hybrids used represent crosses of over 40 diverse parent species, most of which are in the white oak group (subgenus *Quercus*). A previous study has shown that the rooting success of oaks propagated asexually using a similar method can differ between species (Amissah and Bassuk, 2007), and preliminary research suggests that the propagation success of individual hybrid oaks would vary depending on the parental species involved in each cross (Gao, 2011).

The objective of this research was to measure the effectiveness of the modified stool bed layering technique on diverse members of the genus *Quercus*, as well as to provide insight into which, if any, parent species consistently yielded hybrid progeny that could be successfully propagated. Additionally, this article identifies and describes in detail a reliable technique to clone oaks. This experiment is part of a long-term project underway at Cornell's Urban Horticulture Institute to select superior urban-tolerant oak hybrids for introduction as named cultivars into the nursery industry. Along with developing a reliable method to clone oaks, the project currently involves screening the developed hybrids for tolerance to alkaline soils (a common issue in urban landscapes) and making long-term observations on growth and landscape performance.

MATERIALS AND METHODS

Trees used in this study were hybrids grown from seed that were developed by Peter Podaras at Cornell University in Ithaca, New York (Podaras and Wells, 2008). During the Years 2004, 2005, and 2006, controlled crosses were made by pollinating seven species of oak trees growing on the Cornell University campus with pollen from 36 species that are native throughout North America, Europe, and Asia. Table 1 details the number of hybrid seedlings developed from each cross. These seedlings were grown in containers for several years, and during the Spring 2008, 345 unique oak genotypes were planted out in a field of Arkport sandy loam with a pH of 6.2 for future use as stock plants. Starting in spring of 2009, and repeated yearly through 2012, these field-grown stock plants were propagated each year using a modified version of the oak propagation protocol developed by Amissah and Bassuk (2009).

Table 1. Hybrid crosses performed and the resulting number of acorn-grown genotypes.

Maternal parent	Paternal parent	Genotypes (no.)
Q. bicolor	OPEN POLLINATED	7
	Q. sp. (unidentified species)	9
	Q. × *bebbiana*	5
	Q. muhlenbergii × *Q. robur*	6
	Q. affinis	3
	Q. aliena	27
	Q. austrina	4
	Q. chapmanii	4
	Q. dentata	7
	Q. fabrei	14
	Q. fruticosa	4
	Q. fusiformis	2
	Q. gambelii	5
	Q. geminata	2
	Q. glauca	1
	Q. graciliformis	11
	Q. libani	3
	Q. lyrata	2
	Q. macranthera	1
	Q. minima	5
	Q. mongolica var. *grosserata*	3
	Q. muhlenbergii	22
	Q. myrsinifolia	19
	Q. phillyreoides	7
	Q. polymorpha	4
	Q. robur	14
	Q. rugosa	13
	Q. spinosa	2
	Q. turbinella	6
	Q. vaseyana	6
Q. 'Ooti'	*Q. fusiformis*	1
Q. × *warei* 'Long'	*Q.* × *comptonae*	17
	Q. × *warei* 'Long'	8

Table 1. Continued.

Maternal parent	Paternal parent	Genotypes (no.)
Q. gambelii ×	Q. × *comptonae*	2
M. macrocarpa	*Q. lyrata*	2
Q. macrocarpa	OPEN POLLINATED	12
	Q. × *comptonae*	1
	Q. × pauciloba (syn. *undulate*)	4
	Q. fusiformis	2
	Q. gambelii	6
	Q. geminata	1
	Q. lyrata	4
	Q. macrocarpa	1
	Q. michauxii	3
	Q. minima	1
	Q. prinoides	13
	Q. turbinella	1
Q. montana	*Q. geminata*	2
	Q. lyrata	1
Q. muhlenbergii	*Q.* × *comptonae*	1
	Q. aliena	2
	Q. fusiformis	16
	Q. geminata	2
	Q. lyrata	3
	Q. michauxii	3
	Q. minima	4
	Q. muhlenbergii	1
	Q. prinoides	6
	Q. virginiana	7

Propagation 2009

Before bud break in May of 2009, each hybrid oak stock plant was cut back, leaving an 8-cm (3-in.) stump. After 2-3 weeks, upon evidence of epicormic bud swelling on the stump, the plants were etiolated. To achieve etiolation, each stump was covered with an inverted #2 container wrapped in heavy-duty aluminum foil to reduce heat accumulation. A brick was placed on top of each container to secure it in place.

When the newly expanded shoots reached approximately 12 cm (4.7 in.) in length, which took ~7 days, the pots used for etiolation were removed. At that time, any shoots less than 5 cm (2 in.) in length were removed, and the basal 3 cm (1.2 in.) section of the new shoots was sprayed with a solution of 8,000 ppm Indol-3-butyric acid (IBA) dissolved in 98% aqueous ethanol.

After the IBA solution dried (~10-15 min after treatment), a #2 bottomless pot wrapped with light-reflective aluminum was placed over each stock plant so that it rested on the surface of the soil. The bottomless pots were filled with pre-moistened PRO-MIX® (a peat-based growing medium by Premier Tech Horticulture®; Main components: Canadian sphagnum peat moss (75-85%/vol.), perlite, vermiculite, dolomitic and calcitic limestone (pH adjuster), macronutrients, micronutrients, wetting agent) to cover the treated shoot bases while leaving the growing tips of the shoots exposed. The tips of the shoots, while coming out of the planting medium, were still contained within the headspace of the bottomless pot.

The openings of the pots were then covered with white plastic perforated with two cuts to reduce humidity. This was done to protect and temporarily shade the etiolated shoots and allow them to gradually acclimate to the increased irradiance levels while greening up. After 2 weeks, the white plastic was removed and the shoot tips were exposed to full sun conditions. Since the stock plants grew at different rates, all treatments were completed in late July of 2009.

The plants were then allowed to grow. Over the growing season, overhead irrigation was used when necessary to keep the medium in the bottomless pots moist. Additional medium was added as the shoots elongated until it entirely filled the bottomless pots. Throughout the summer, the lengthening shoots were pruned back to approximately 60 cm (23.6 in.) to reduce ultimate shoot height.

The plants were allowed to grow until early November when the bottomless pots and the growing medium were removed, and the rooted and unrooted shoots were harvested from the stock plants. Shoots that had developed roots were potted up with PRO-MIX in #1 containers. During harvesting, the number of total shoots and the number of rooted shoots were recorded for each stock plant. The potted oaks were thoroughly watered, then placed in an unheated covered overwintering structure for winter dormancy.

Propagation 2011

The propagation procedure was repeated in 2010 with a few adjustments. The IBA concentration was reduced from 8,000 to 6,000 ppm in 98% aqueous ethanol, and it was applied with a soft paintbrush instead of a spray bottle. Rather than using white plastic for shading and the acclimatization of the etiolated shoots to full sun, silver-colored, light-reflective metal mesh trashcans approximately 30×30×35 cm (12×12×14 in.) in size were used to cover and shade the shoots following etiolation. After the shoots gradually greened up under the shade for approximately 1 week, the trashcans were removed.

Propagation 2011 and 2012

A few adjustments were made to the 2010 procedure for use in both 2011 and 2012. Rather than harvesting and potting up the rooted shoots in the fall, they were left until the spring, allowing the shoots to undergo dormancy while still attached to the stock plants. The shoots were then harvested before bud break. Also, rather than using bottomless #1 pots wrapped in aluminum foil for the layering step of the procedure, a section of white PVC pipe, approximately 15.25 cm tall with a diameter of 16.5 cm (6×6.5 in.), was employed. The IBA concentration was also increased back to 8,000 ppm from 6,000 ppm. Figure 1 illustrates the procedure used during these years and Table 2 details the suggested protocol for rooting *Quercus* spp. using this technique.

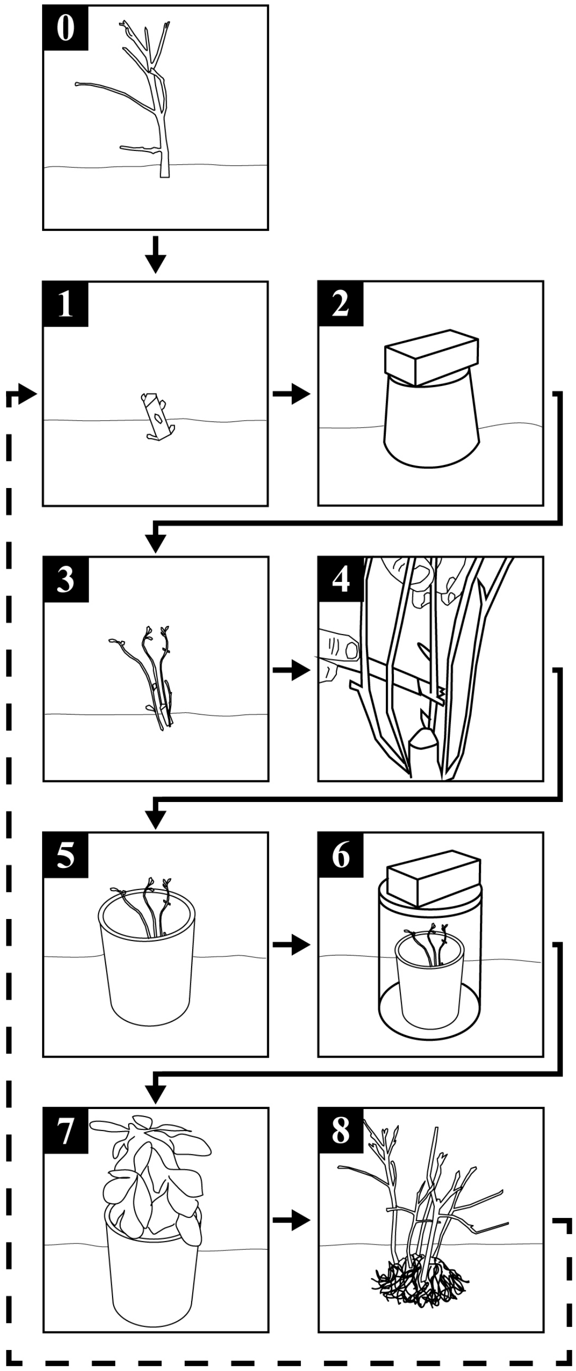

Fig. 1. Field layering procedure for *Quercus* spp. The oaks are planted in a field and grown for 1 to 2 years for future use as stock plants (0). In spring, while the plant is dormant, it is cut back to an 8-cm stump. When the buds begin to swell (1), the plant is covered for etiolation (2). The container used for etiolation is removed 1 week later (3). At this time, IBA is painted onto the bases of the new shoots (4). A bottomless container is then placed over the stock plant and filled with a soilless medium (5). The plant is then covered with a metal mesh trashcan to temporarily shade the plant as it becomes acclimated to full sun (6). After the trashcan is removed, the plant is allowed to grow all season and the medium in the bottomless

pot is kept moist (7). The following spring, the pot and medium are removed, and the shoots — which hopefully have rooted — are then harvested from the stock plant (8). The entire procedure can be repeated the following year.

Table 2. Suggested protocol for rooting *Quercus* spp.

Time		Action
Time 0	Immediately prior to bud break	Stock plants cut back to ~8 cm above soil
Week 2-3	Buds start expanding	Stumps covered with #2 containers that are wrapped in aluminum foil and secured with brick for etiolation
Week 3-4	~7 days later	Containers removed. IBA applied to base of newly developed shoots. Bottomless pot placed over shoots and filled with soilless medium. Stock plant covered with a metal mesh trashcan for shading
Week 4-5	~7 days later	Trashcans removed
Throughout growing season		Plants pinched back to ~60 cm, and medium is kept moist to encourage rooting
Following spring, before bud break		Rooted shoots harvested. Protocol can be repeated in following years

Statistical Analysis

Statistical analysis of the data was done using SAS statistical software (SAS Institute Inc.) and the unit for analysis was a single shoot. Due to the large number of paternal parent species, and the fact that many hybrid crosses were represented by only a few genotypes, the data was pooled by maternal parent species, and the data from all 4 years were combined for analysis. Table 3 summarizes the number and diversity of stock plants (genotypes) when sorted by maternal parent species. The effect of the maternal parent species on the total number of shoots produced annually by a stock plant and the effect on the probability of a shoot to produce roots were studied.

Table 3. Summary of hybrid *Quercus* crosses sorted by maternal parent species.

Maternal parent	Unique hybrid crosses (no.)	Unique genotypes (no.)
Q. bicolor	30	218
Q. gambelii × *Q. macrocarpa*	2	4
Q. macrocarpa	12	49
Q. montana	2	3
Q. muhlenbergii	10	45
Q. 'Ooti'	1	1
Q. × *warei* 'Long'	2	25

In order to study the effect of the maternal parent species on the number of shoots produced, a generalized linear mixed model using a Gauss-Hermite quadrature method with a Poisson distribution and log link was employed. For studying the effect of maternal parent on the likelihood of a shoot to produce roots, a generalized linear mixed model with a binomial distribution and logit link was used. For both regression analyses, the combination of parents (hybrid species) was controlled for as a random effect. Least squares means was used to estimate the number of shoots a stock plant produced annually and the probability of a produced shoot to root based on the maternal parent. The Tukey-Kramer method was used to compare differences of maternal parent least square means with differences being considered significant when $P<0.05$.

RESULTS AND DISCUSSION

Shoot Production

The mean number of shoots produced annually by stock plants varied significantly between maternal parent species (Table 4). The mean number of shoots produced annually was highest in the hybrid with *Quercus* 'Ooti' as a maternal parent (8.9 shoots/year) and lowest in *Quercus bicolor* (4.8 shoots/year) (Table 5). The Tukey-Kramer HSD test reveals that *Q. bicolor* and *Q. macrocarpa* values are significantly different ($P<0.05$) when compared to *Quercus* 'Ooti' and *Q. muhlenbergii* (Fig. 2). It should be noted that the limited number of stock plants with *Q.* 'Ooti', *Q. montana*, and *Q. gambelii* × *Q. macrocarpa* as a maternal parent (Table 3) resulted in high standard error values of over 1.0 for these three species (Table 5).

Table 4. Statistics of number of shoots produced by stock plants by maternal parent.

Effect	Num DF	Den DF	*F* value	Prob>*F*
Maternal parent	6	52	2.96	0.0146

Table 5. Estimated annual number of shoots produced by maternal parent.

Maternal parent	Estimate number of shoots	Standard error	Prob > |t|
Q. bicolor	4.8	0.2	<0.0001
Q. gambelii × *Q. macrocarpa*	6.7	1.1	<0.0001
Q. macrocarpa	5.2	0.4	<0.0001
Q. montana	6.2	1.1	<0.0001
Q. muhlenbergii	6.2	0.4	<0.0001
Q. 'Ooti'	8.9	2.2	<0.0001
Q. × *warei* 'Long'	5.4	0.7	<0.0001

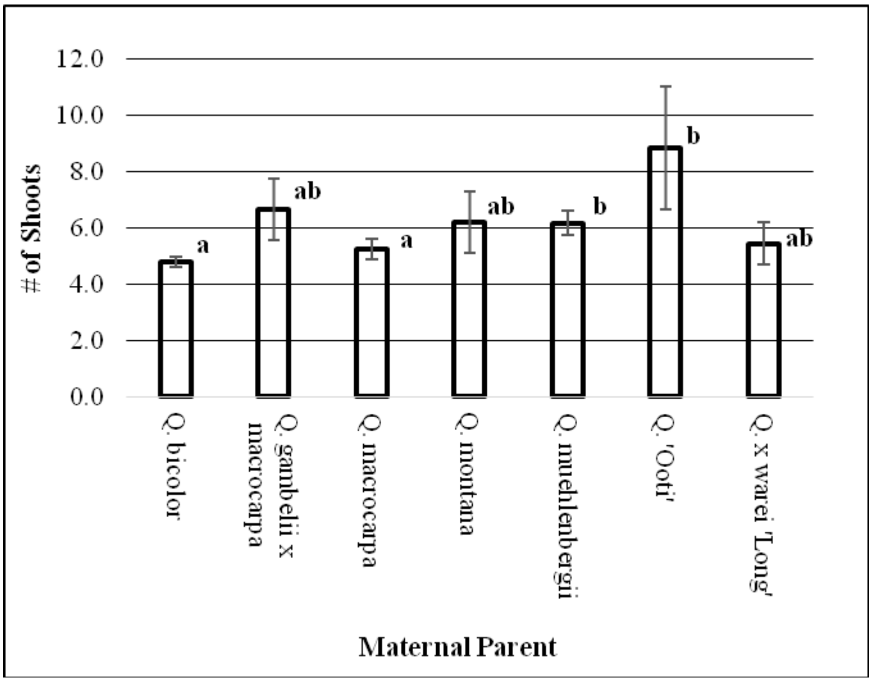

Fig. 2. For the yearly number of shoots produced by stock plants, estimates based on the maternal parents were found to be significantly different (*P*<0.05). Different letters indicate significant differences (*P*<0.05, Tukey-Kramer HSD test). Error bars represent calculated standard error.

Rooting Probability

The probability for a shoot to develop roots varied significantly between the maternal parent species. Table 6 summarizes the statistical analysis. The probability for a shoot to develop roots was highest in the hybrids with *Q. gambelii* × *Q. macrocarpa* as a maternal parent (62.3%) and lowest in *Q. muhlenbergii* progeny (7.0%) (Table 7). The Tukey-Kramer HSD test reveals that values for *Q. bicolor*, *Q. gambelii* × *Q. macrocarpa,* and *Q. muhlenbergii* were all significantly different (*P*<0.05) from each other (Fig. 3). Similar to the statistical analysis of the number of shoots produced annually, the limited number of stock plants with *Q.* 'Ooti', *Q. montana*, *and Q. gambelii* × *Q. macrocarpa* as a maternal parent resulted in high standard error values of over 12%. *Quercus* × *warei* 'Long' also had a high standard error value over 12%. Additionally, these four species had Prob > |t| values greater than 0.05.

The relatively high rooting probability associated with the maternal parent *Q. gambelii* × *Q. macrocarpa* might be related to the fact that *Q. gambelii*, the Gambel oak, is a shrubby species native to the southwestern USA that spreads by rhizomes (Grimshaw and Bayton, 2009). *Qercus* 'Ooti' is also associated with high rooting probability. *Quercus* 'Ooti' is a cultivar of difficult to determine origins and is supposedly a selection of the complex hybrid *Q. robur* × *Q. macrocarpa* × *Q. muhlenbergii* (Pavia Nursery). Because *Q.* 'Ooti' is only represented by a single cross and genotype (Table 3), the high rooting probability might be connected to the paternal parent species involved ~ *Q. fusiformis*, the Texas live oak. This is another shrubby species from the southwestern USA that spreads by rhizomes (Grimshaw and Bayton, 2009). On a related note, for the long-term goals of this project, it is of interest to observe the mature growth habit of all of the developed oak hybrids, especially those that involve *Q. gambelii, Q. fusiformis*, or any of the other rhizomatous shrub species used.

Table 6. Statistics of the probability of a shoot to root based on maternal parent.

Effect	Num DF	Den DF	*F* value	Prob > *F*
Maternal parent	6	52	7.82	<0.0001

Table 7. Estimates for probability of shoots to root by maternal parent.

Maternal parent	Estimate of rooting probability (%)	Standard error (%)	Prob > |t|
Q. bicolor	19.4	2.2	<0.0001
Q. gambelii × *Q. macrocarpa*	62.3	12.7	0.359
Q. macrocarpa	27.4	4.7	0.0001
Q. montana	33.7	13.0	0.2494
Q. muhlenbergii	7.0	1.8	<0.0001
Q. 'Ooti'	60.0	18.8	0.6083
Q. × *warei* 'Long'	48.8	12.7	0.9229

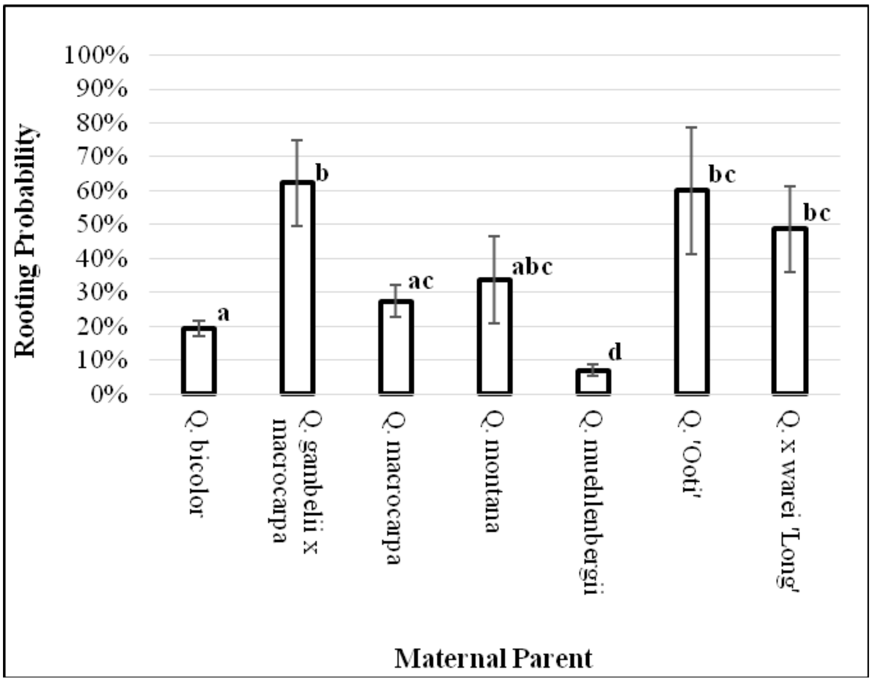

Fig. 3. For the probability of shoots to produce roots, estimates based on the maternal parents were found to be significantly different (*P*<0.05). Different letters indicate significant differences (*P*<0.05, Tukey-Kramer HSD test). Error bars represent calculated standard error.

CONCLUSIONS

These results have shown that the described propagation method can be utilized to clone genetically diverse members of the genus *Quercus*. However, out of the 345 unique genotypes originally involved in the study, 88 of the stock plants had died by 2012, and only 235 of them produced rooted shoots at any point during the 4 years. This suggests that there is more to learn about developing a successful asexual propagation method for diverse *Quercus* species. Moreover, the number of rooted shoots produced annually by a stock plant will likely need to increase for this method to become a viable commercial propagation practice. It is expected that the described propagation method, which has proven successful on a diverse range of oaks, could be further optimized to have greater success on a given species, hybrid, or cultivar of interest.

The results of this study provide guidance to plant breeders interested in creating oak hybrids and suggest that certain maternal parents are preferable to others if the goal is to create hybrids that can be asexually propagated in good numbers using the described method. Additionally, the findings will be used to select from the hybrids the genotypes that are highly propagable for future observation. With completion of this study, Cornell's Urban Horticulture Institute is one step closer to realizing the goal of selecting and introducing named cultivars of superior urban-tolerant oak hybrids.

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Mechanized Seedling Production at Bailey Nurseries©

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Consistently producing line-out stock for species shrubs and trees and understocks for budding have been a part of Bailey Nurseries, Inc. since the beginning. It is great to be a part of that tradition of starting durable and dependable seedling line-outs. Most of those line-outs are developed solely for bare-root field planting, sales and for container planting. At the propagation facilities in Cottage Grove, Minnesota (MN), the seedling department is a small dedicated operation that focuses on cost effectively managing the production of roughly one million seedling line-outs in single year production cycle. What follows is a description of what we do to make that happen.

At our Minnesota seedbeds we are growing 80 species of trees and shrubs from seed. Seedling crops are regularly monitored in the seedbeds throughout the growing season to evaluate acceptability for continued use as a seed source for the future. Sugar (*Acer saccharum*) and red (*Acer rubrum*) maple are plants that we have made several selections from (MN) originated sources for superior plant growth characteristics. Two or more selections of each maple have been cloned and lined in our orchards in Sunnyside, Washington (WA), to rear the highest quality seed and seedlings for Bailey Nurseries bare-root production. Around 30% of our annual seed needs are supplied by our orchard at Sunnyside, WA, and that percentage is growing. Roughly 40% of our annual seed needs are hand collected from trees and shrubs located around the greater Twin Cities (MN) area as well as a select few from northern MN. Scouting for superior landscape adaptable plants becomes as much of a past-time as it is a component of routine trips to check on the current years seed crop.

We currently operate on a parcel of land with 31 tillable acres. At our current production levels we are annually planting 17 acres of land in seedbeds. Postharvest we rip each field in the fall to a 24-in. working depth and chisel plow and lightly cultivate in the spring to plant a cover crop of Glyphosate® resistant corn or daikon radish depending on the most persistent field issue. Post cover-crop each field will be chopped, chisel plowed and cultivated to a finished bedding condition for bed forming. Fields are bedded 4 to 6 weeks in advance of planting to manage weed pressure before and if possible after crop sowing.

We currently mechanically sow around 90% of our annual seedling production schedule. We utilize a common hopper gravity-fed vegetable planter. This seed planter is capable of sowing seed from the size of *Populus tremuloides* to *Prunus americana*. With this equipment we can uniformly apply seed sowing densities in rows at planting depths of our choosing or surface scattered. We have found that six, double-shoe planted rows works the best for our situation. A uniform seed flow rate is critical to achieve consistent densities. When necessary, pre-moistened seeds are sown with a light coating of talc powder or powdered graphite. After sowing we cover each bed with a ⅜ - ½ in. of coarse grade sand.

Weed control is paramount in consistently producing a high quality seedling crop in a single growing season. Common groundsel (*Senecio vulgaris*) and purslane (*Portulaca oleracea*) are our top weed issues in the seedbeds. In an effort to reduce the economic impact of hand-weeding labor costs we utilize charcoal and herbicide banding on row sown beds. These are liquid applications that are applied at the time of sowing and are then covered with a layer of sand. Application rates of herbicide will vary with the timing of sowing, but the charcoal layer is consistent. Careful attention to irrigation volume is needed to promote activity of the herbicide between the rows and to prevent lateral migration of herbicide in the bed profile. This technique continues to be a work in progress, but is currently applied to approximately 60% of all of our row-sown crops.

Minnesota winters can be a harsh environment for growing in seedbeds. The months of cold are not as critical as long as there is enough snow. We tend to have poor germination where the seedbeds are exposed to the harsh winter with little snow cover. A uniform stand of seedlings is best achieved in a cool and evenly moist seed stratifying bed. In Minnesota we use an even layer of rye or wheat straw at a depth of 3 in. over every surface of the bed. That straw is windrowed on each bed. Each bed is then spread via a tractor drawn hydraulically operated rake. The rake has two multi-axis articulating drums that operate perpendicular to the bed for covering the bed evenly in a single pass. For uncovering seedbeds in the spring the drums move the straw from the bed to the furrow when each drum is turned at 45^{o} to the length of the bed. This single pass covering and uncovering allows for timely and cost effective winter protection of Minnesota seedbeds.

Bailey Nurseries success in growing is based on building and establishing a good root system. Our growing and plant cultivation strategies are dedicated to building a high quality root system. For the crops that we have undercut, root pruning timing is what makes the difference. If the plant is severed later in the growing season size yields are certainly going to be reduced and the recovery period is long. We look to head the root radical back when the plant is young and the roots are fleshy. Small cuts made in the earlier part of the season still have an effect on size yields, but not as much time passes waiting recovery from the procedure. Ground moisture is important to reduce excessive plant and soil shifting, but is balanced against the potential for soil glazing from the passage of the blade.

Grading seedlings at Bailey Nurseries is still done in a similar format to the way we’ve graded for the last 30 years. One grader is responsible for every grade. Each plant type is graded in order of the most prevalent size relative to the order on hand. We only process as many seedlings as we have orders. Each plant type is graded, prepared for planting or sales, and packaged away for winter storage in a single handling. Plants are held at varying storage conditions based on what works most successfully for our own needs.

Plant Propagation for the Breeding Program at Chicago Botanic Garden©

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INTRODUCTION

The Chicago Botanic Garden, The Morton Arboretum, and the nursery consortium Ornamental Growers' Association of Northern Illinois (OGA) are the corporate members of the Chicagoland Grows®, Inc., plant introduction program. Founded in 1986, the introduction program is dedicated to the development, testing, and introduction of landscape plants to the industry, gardens of the Midwest, and comparable climates in the USA, Canada, and Europe. In support of Chicagoland Grows, Chicago Botanic Garden initiated a perennial plant breeding program in 1995, which has developed to date the Prairieblues™ false lupins, the Meadowbrite™ coneflowers, and other selections.

Plant propagation at Chicago Botanic Garden supports the breeding program in two general ways. The breeding program produces seed from controlled crosses, which are then germinated in-house and grown on for further breeding. Once individual plants are selected for testing as potential introductions, then vegetative propagation protocols are applied to ensure the genetic integrity of the propagated plants. The remainder of this paper will present the seed and vegetative propagation protocols we have utilized for selected genera in the breeding program. The Chicago Botanic Garden is in northern Illinois in U.S.D.A. Zone 5a, for comparison of propagation dates in other regions.

SELECTED GENERA IN THE BREEDING PROGRAM

Asclepias (Milkweed) Propagation (*Asclepias tuberosa* and *A. purpurascens* Hybrids)

1. Seed. Ripe seed was collected from dehiscing fruit of various species and several hybrids in early autumn. The actual seeds are separated from the silky pappus (the parachutes). Seed viability is easy to discern in *Asclepias* as the linear embryos are readily visible by candling the seeds over a light source. We air-dried seeds for several days to several weeks, then cold stratified in damp sand at about 35-38°F for 12 weeks. Seed was sown in PT128 trays in March in a plug mix with a light covering of vermiculite and then placed under mist on 70°F bottom heat. Seedlings began to emerge within a few weeks. Move the seedlings along quickly and plant them out the same year as in-ground establishment is difficult if their taproots become at all potbound. Plants will bloom the following year, some in the first year.

2. Root Cuttings. A group of hybrid milkweed plants were grown for 3 years in a raised sand bed filled with a coarse builder's sand and leaf compost mix. This planting medium ensured ease of digging up roots. Dormant roots were then dug out of the raised bed in March. The roots used for propagation were cut into pieces approximately 1 to 3 in. in length and approximately ½ to 1 in. in diameter. Small, dormant, adventitious shoots were visible on some of the root pieces. The root cuttings were potted in 2½-in. pots in a well-draining bark mix and put into a greenhouse at a minimum of 65°F air temperature. Shoots emerged within 1 month-plus from 70% of the pots. As a side note, the roots remaining in the raised bed responded to their disturbance by sending up a proliferation of shoots that summer. This technique works well for the maintenance and propagation of selected milkweed clones. Plants will bloom the following year, some in the 1st year.

Symphyotrichum, Aster, Propagation (syn. *Aster ericoides*, *A. novae-angliae*, *A. oblongifolius*, and Hybrids)

1. Seed. Ripe seed is collected from mid-October to early November. Luckily our northern native asters are adapted to ripening their seed quickly after fall flowering, and seed maturation is not affected by intermittent light frosts or freezes. The seeds are air-dried for upwards of several weeks, manually separated from their bristly pappus, then mixed with moist sand in small plastic envelopes, and stratified at 35-38°F for 12 weeks. The seeds are then sown in March in PT128 trays in a plug mix with a light covering of vermiculite and placed under mist on 70°F bottom heat. Seedling emergence occurs within a few weeks, and plants are large enough to plant out that summer. All the plants bloom the first year.

2. Cuttings. Cuttings are taken in late May into late June before flower buds are initiated. The basal portion of each cutting is dipped for 5 s in an aqueous solution of 1,250 ppm K-IBA and then stuck in a rooting medium of perlite and peat moss (2:1, v/v) in a CP72 plug tray. Cuttings are maintained in a fog house at 96% relative humidity and 68°F minimum air temperature with supplemental bottom heat at 75°F. Rooting is typically 100% within weeks. When cuttings are stuck in the rooting medium, it is imperative at least one or two vegetative nodes are stuck into the medium as it is from these buried nodes that an overwintering bud is formed. Otherwise, plants will have a much lower survival rate the following spring. Cuttings can also be stuck directly in larger SVD-2 and SVD-3 pots, which allow greater medium depth under the base of the deeply stuck cutting. Rooted cuttings will form good-sized flowering plants the same year.

***Baptisia*, False Lupins, Propagation (Multiple Species and Hybrids of the Prairieblues™ Series)**

1. Seed. Because we generally sow a limited amount of seed, we used sand paper to scarify each seed individually. *Baptisia* seed tend to have softer seed coats than other members of the pea family (Fabaceae), notably woody legumes such as *Cercis*, which can be scarified with concentrated sulfuric acid. Whatever method is used to scarify the seed, care must be taken not to cut all the way through the seed coat and into the underlying embryo and cotyledon tissue. After scarification, the seeds are soaked in water for 24 h then cold stratified in damp sand at about 35-38°F for 4 weeks. Seed is then sown in February in PT128 trays in a plug mix with a light covering of vermiculite, and then placed under mist on 70°F bottom heat. Seedling emergence is staggered over the next several months, likely due to varied seed coat thickness and possibly other dormancy factors. Plants are potted and planted out in spring of the following year and will be 2 to 3 additional years to blooming size.

2. Cuttings. Shoot-tip cuttings are taken as the vegetative growth is nearly finished and while the stems are still pliable, but the terminal is nearly finished elongating. In northern Illinois, this will typically be about mid-June. We take fairly long shoot tip cuttings, 3 in. in length, shorter for the more compact selections. The critical key to success is to stick the cuttings with at least one, and possibly two, unbranched nodes inserted into the rooting medium. One of these dormant axillary buds will become the overwintering bud in the pot the first winter; if there isn't an axillary bud in the rooting medium, the chances of plant emergence the following spring drops dramatically (Conner and Bir, 2001).

For rooting we use 1,250 K-IBA for a standard 5 s dip. A well-drained medium is optimal, such as a peat and perlite (1:1, v/v) mix (Note: this mix may dry out too readily after rooting, may want to modify slightly). Use a fairly deep pot for rooting since there is a good 1 to 1.5 inches of stem inserted into the medium. A plug tray won't work well as the basal end of the cuttings will be too deep in the plug, where it can be waterlogged. We have used an SVD-2 pot, 32 to a tray, for years quite successfully. Several of our licensed nurseries use SVD-3 or SVD-4 pots or their equivalent and stick two cuttings to a pot to ensure they have a fuller looking plant the following year. Treated cuttings are placed under mist. Most cuttings will root in 3 weeks though there will always be some laggards. The earlier you can root the cuttings, the higher the rooting percentages, and overwinter survival will be greater. Overwinter in a minimum heat polyhouse and keep them a bit on the dry side. We have rooted cuttings as late as August, but then had difficulty overwintering them. A small percentage of the plants will bloom the following year, and all of them should bloom the 2nd year.

***Echinacea,* Coneflower, Propagation (*E. purpurea*, *E. tennesseensis*, *E. paradoxa* and Hybrids of the Meadowbrite™ Series)**

1. Seed. Ripe seed is collected from late August to early October, species dependent. Bag the inflorescences during seed ripening to prevent goldfinches from stripping the seed. The seed is air-dried for upwards of a month, cleaned, then cold-stratified in damp sand at 35-38°F for 12 weeks. Seed is then sown in March in PT128 trays in a plug mix with a light covering of vermiculite. The trays are placed under mist on 70°F bottom heat. A quick flush of germination tends to occur within several weeks, then sporadic germination afterwards. The more complex interspecific hybrid seed no doubt has more complex dormancy mechanisms derived from their different parent species, leading to more sporadic and complicated germination. Seedlings can be planted out in the first year or grown on for planting the 2nd year. Some seedlings will bloom the 1st year, and all will do so the 2nd year.

2. Tissue Culture. Field-grown plants are dug up in late autumn, potted in a well-draining soilless medium, and then stored in a minimum heat polyhouse for several months. Plants are then greenhouse-forced into new growth starting in January-February of the following year. The most efficient explant is leaf petiole tissue from expanding basal leaves. The leaf petioles are surface disinfested for 12 min. in an aqueous 20% commercial bleach solution then rinsed for 10 min. in sterilized distilled water. The leaf petioles are then aseptically cut into 0.5-1.0-cm-long segments and placed on initiation medium abaxial (back) side down. The initiation medium consists of Murashige and Skoog (MS) basal medium and vitamins, 30 $g \cdot L^{-1}$ sucrose, 2.5 µM or 0.556 $mg \cdot L^{-1}$ of benzyladenine (BA), 0.5 µM or 0.113 $mg \cdot L^{-1}$ of potassium salt of NAA (K-NAA), adjusted to a pH = 5.7 to 6.3, and solidified with 7 to 9 $g \cdot L^{-1}$ agar. If the explants are sufficiently juvenile, adventitious shoots should appear on the cut ends and on the top of the explant in 3-4 weeks. If adventitious shoots are really small or there is no response after 4 weeks, subculture to fresh initiation medium for another 4-week period. Once shoots are initiated, they can be transferred to multiplication medium for continued shoot growth and axillary proliferation. The multiplication medium is the same as the initiation medium except the K-NAA is eliminated and the BA is decreased to 0.5 µM or 0.111 $mg \cdot L^{-1}$. Shoots can be divided and recultured on fresh multiplication medium every 3-4 weeks. Plant growth regulator-free medium works best for shoot rooting. Addition of IBA or NAA to either multiplication or rooting medium will stimulate callus growth, which should be avoided as it interferes with proliferation and rooting. All cultures were maintained in incubators with 12 to 14 h of light/day and 20-22°C. Rooted shoots are easy to acclimate in the greenhouse under fog or mist and on bottom heat.

***Phlox* Propagation, Moss Phlox, Summer Phlox (*P. subulata* Selections, *P. glaberrima*, *P. maculata*, *P. paniculata*, and Hybrids)**

1. Seed. Seed is collected any time from June into September, species or hybrid dependent. The spring-blooming moss phlox, such as *P. subulata* and *P. nivalis*, can ripen their seed in as little as 30 days; whereas the summer blooming *P. maculata* and *P. paniculata* tend to take 45 days or longer to mature their seed. Seed is cleaned, air-dried for at least several days, and then stored under refrigeration until sown. In late September, the seed is sown in PT128 trays in a plug mix with a light covering of vermiculite. These are placed under mist on 65°F bottom heat for a month. The trays are then moved to a minimum heat quonset that is kept above freezing, but experiences daily temperature fluctuations, especially on sunny days. Seeds from some of the spring blooming moss phlox adapted to very early growth or to high elevations will sporadically germinate while in the quonset. They are kept damp by hand-watering and the germinated seedlings removed to a greenhouse for growing on. The flats are then brought back into the mist house after 12 weeks. Usually there is a rapid flush of germination within a week when the flats are brought back to the mist house, then several more weeks of sporadic germination. The flats are given another cold treatment after 12 weeks in the mist house by putting them into a refrigerator at 35-38°F for 8 weeks; then they are moved back to the mist house. The flats are also put back in the minimum heat quonset for a 2nd winter. Each time the flats are moved back to a warm environment there will often be another immediate small flush of germination followed by a few sporadic-emerging seedlings.

2. Cuttings. Shoot-tip cuttings are given a 5-s dip in 1,250 ppm K-IBA; the cuttings are stuck in perlite and peat moss (2:1, v/v) in CP72 cell trays and then placed under mist. The spring blooming moss phlox prefer cooler temperatures for rooting, and so bottom heat is not advised. These cuttings should be taken immediately after the plants finish blooming, typically in May for us. Cuttings from the summer-blooming taxa can be taken from June into October, as long as there is active shoot growth for shoot tip cuttings. These are treated as above and placed on 75°F bottom heat. Rooting for all types typically approaches 100% in about 4 weeks. The spring blooming types are typically grown on for planting out the following year, whereas the summer flowering taxa can be planted out the same year if rooted early enough or overwintered for planting the following year. All of these types will bloom the following year.

***Polygonatum* 'Prince Charming' (Solomon's Seal)**

1. Division. Brent Horvath from Intrinsic Perennial Garden in Hebron, Illinois, the originator of this selection, sells bare-root dormant divisions taken from stock plants in January to March before the plants emerge. A one or two-eye division with 1-2 in. of rhizome are recommended for a 4-in. pot. Active plants can also be divided over summer any time after they are done flowering. Plants will form nice small flowering clumps the following year.

***Tradescantia* 'Tough Love' (Spiderwort)**

1. Division. Field-grown plants dug in the fall and stored in a minimum heat quonset have been divided in March then potted into a well-draining bark mix in 3½-in. pots. These are kept in the greenhouse at 65°F and are all well rooted after about a month. Plants will bloom the same year and will be large enough to divide again by the following year. Stock plants can be kept in pots year-round for early spring division. Fall division of freshly dormant plants would likely work as well.

***Veronica*, Groundcover Speedwells ('Whitewater' and Hybrids)**

1. Seed. Seed is collected in July to August, taxon-depending. They are air-dried, then extracted from the small heart-shaped fruit, and stored under refrigeration until sown. Seed is sown March in PT128 trays in a plug mix with a light covering of vermiculite, then placed under mist on 70°F bottom heat. Germination takes place within a few weeks. Seedlings can be grown on for planting out the same year or the following year. The seedlings should all bloom the second year from seed. This protocol has worked for spike speedwells (*V. spicata*, *V. spicata* subsp. *incana*, etc.)

2. Cuttings. Shoot-tip cuttings can be taken from field grown or container grown stock plants as long as the shoots are in active growth. Cuttings have been rooted in March, May, June, and August with equal success. Other months would likely work. The basal end of shoot-tip cuttings approximately 2 in. in length are treated with a 5-s dip in an aqueous solution of 1,250 ppm K-IBA. Cuttings are then stuck in CP72 pots (cell packs 72 per flat) containing a medium of perlite, peat, and sand (2:1:1, by vol.). A rooting medium perlite and peat (2:1, v/v) is also as effective. Pots are placed in a fog greenhouse with bottom heat of 75°F and air temperature of 70 to 80°F. All the cuttings root within weeks. Plants are container grown until the following year, when they should all bloom.

3. Division. While we have not attempted division with these plants, the fact that their shoots readily layer into the ground suggests these can be lifted and divided, probably best immediately after blooming in late spring.

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Breeding Better *Aronia* Plants©

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INTRODUCTION

The genus *Aronia*, commonly known as chokeberry, is a genus of deciduous, multi-stemmed shrubs native to eastern North America. Three species of chokeberry are commonly accepted: *A. arbutifolia*, red chokeberry; *A. melanocarpa*, black chokeberry; and *A.* × *prunifolia*, or purple chokeberry. The third species, *A.*× *prunifolia*, is generally considered to be a naturally occurring, interspecific hybrid between *A. arbutifolia* and *A. melanocarpa* (Brand, 2010; Dirr, 2009; Rehder, 1920). Most sources distinguish the species by either red or black fruit color (Hardin, 1973), plus the degree of pubescence on leaves, stems and inflorescences (Krussmann, 1986). *Aronia arbutifolia* possesses dense tomentum on the undersides of leaf blades, stems, and inflorescences compared to nearly glabrous *A. melanocarpa*. Brand (2010) demonstrates both extremes of fruit color and pubescence can be observed in *A.* × *prunifolia*, indicating additional characteristics such as fruit ripening times, ploidy, geography, and DNA marker information are required for accurate identification. The genus *Aronia* belongs to the *Rosaceae* subtribe *Pyrinae* (formerly subfamily *Maloideae*) which includes *Sorbus* (mountain ash), *Malus* (apple), *Pyrus* (pear), *Amelanchier* (serviceberry), *Crataegus* (hawthorn), and several other woody plants with pomes or apple-like fruits (Campbell et al., 2007; Gleason and Cronquist, 1991; Robertson et al., 1991).

ARONIA AS AN ORNAMENTAL CROP

Aronia is widely adaptable and performs well under a range of cultural conditions. It is a multi-season ornamental which produces showy white flowers in spring, red or black fruits in the summer or fall, and showy orange and red fall foliage color. The chokeberries have been recommended as native replacements for exotic invasive shrubs including *Euonymus alatus* and *Berberis thunbergii* (Abbey, 2004). There are two main ornamental black chokeberry cultivars, both are semi-compact forms: 'Autumn Magic' and 'Morton' (Iroquois Beauty™) (Dirr, 2009). 'Brilliantissima', the dominant red chokeberry cultivar, is supposed to possess larger fruit, glossier foliage, better plant habit, more intense fall color, and prolonged leaf retention than the species. Preliminary observation suggests that some wild types in our current germplasm collection may be superior to 'Brilliantissima' for fall color, habit, and leaf retention.

ARONIA AS A FRUIT CROP

In the 19th century, black chokeberry was introduced to Russia where it was originally intended for berry production in home gardens. Since the 1940s, it has been cultivated as a commercial fruit crop in Russia (Kask, 1987), where the berries are processed and the juice is used for a range of products. In 1984 there were 17,800 ha of chokeberry cultivated in the Soviet Union. *Aronia* berries, while edible as a fresh fruit, are much tastier when the fruits have been processed. *Aronia* berries are very suitable for industrial processing since they are not prone to mechanical damage during transport and have low pectin content (Jeppsson, 1997). Moreover, *Aronia* berries can be harvested by machine (Gatke and Wilke, 1991) and there is a long harvest window. *Aronia* juice is blended with other more flavorful juices such as apple, cranberry, grape, and black currant juice to make popular juice beverages. Other common uses include jellies and jams, syrup, soft spreads, teas, wine, and to flavor ice cream and yogurt. *Aronia* juice is also an excellent colorant.

The University of Wisconsin-Madison Center for Integrated Systems (Secher, 2008) evaluated 13 potential uncommon fruits with sustainability potential. *Aronia* was chosen as the crop with the greatest potential, beating out currants, gooseberries, and elderberries. Low input requirements, high adaptability, high pest resistance, high nutraceutical content, short time to first yield, ease of culture, and high machine harvest potential were given as reasons why *Aronia* is tops for commercial production potential.

There is growing evidence that chokeberry consumption can have numerous and varied health benefits (Kokotkiewicz et al., 2010). Aronia berries are valued for antioxidant capacity and gastroprotective effects, anti-inflammatory, and antidiabetic properties, for immunomodulatory activities, and suppression of colon cancer (Bermúdez-Soto, 2007; Sueiro et al., 2006). Aronia is among the richest food sources of polyphenols due to its anthocyanin and proanthocyanidin content, and is among the best sources of quercetin in edible berries (Häkkinen et al., 1999; Perez-Jimenez, 2010).

ARONIA GERMPLASM

Various researchers have recognized that wild germplasm represents one of the best ways to expand the genetic diversity in commercial *Aronia* cultivars (Persson Hovmalm et al., 2004). We hold the world's largest *Aronia* germplasm collection that contains 106 wild accessions collected from the following states: AL, CT, DE, FL, IN, MA, MD, ME, MI, NY, NC, NH, OH, PA, TN, TX, VA, VT, WI, and WV. Additional wild accessions are from Ontario, Canada. The wild *Aronia* germplasm is comprised of 19 *A. arbutifolia* accessions, 57 *A. melanocarpa* accessions, and 41 *A.* × *prunifolia* accessions. Forty four new *Aronia* accessions have been contributed to the National Plant Germplasm System which has tripled the U.S.D.A. holdings of this genus.

Aronia accessions are established at the University of Connecticut in a common planting containing three replicates of each accession. Plants are maintained in clean cultivated rows with mowed grass alleys between rows. All plants receive full sunlight and are lightly fertilized once each spring. Accessions are well-established and reproductive so they can be evaluated for growth, performance, and fruit production characteristics and serve as a genetic resource for an *Aronia* breeding program. Study of the germplasm collection has been conducted from 2008 to present and plants have been evaluated for plant growth rate, plant size, plant habit, flowering date, fruits per infructescense, infructescences per stem, fruit ripening date, fruit color and transition, fruit weight, and fruit diameter.

We have found that there is considerably more variation within the genus *Aronia* than has been reported in the literature or has been understood by the scientific community. Of particular interest for breeding new commercial black chokeberry cultivars is the variation we have found in plant habit, fruit ripening date, fruit size, and phytochemical composition. Plant habit can vary from distinctly upright and tall to very low growing and prostrate. Previous to our germplasm collecting, prostrate forms were not reported. Prostrate forms are able to confer a compact habit to their progeny, regardless of the other parental genotype. We have also found significant variation within red chokeberry for fruit ripening date, fruit size, and ripe fruit color. Some more compact forms of *A. arbutifolia* do exist, but none are prostrate growers as were found for *A. melanocarpa*.

PLOIDY AND APOMIXES

Based on our analysis of wild collected *Aronia*, all *A. arbutifolia* exists as tetraploids, although literature references suggest that both diploids and tetraploids exist. *Aronia* × *prunifolia* also exists as tetraploids, with the rare occurrence of triploids. We did not find any diploid *A.* × *prunifolia*. Within *A. melanocarpa*, that is where things get interesting as far as ploidy is concerned. Wild *A. melanocarpa* from New England are diploid, while *A. melanocarpa* from all other parts of its natural range are tetraploids.

Ploidy is an important breeding consideration for *Aronia*, since we believe that polyploids produce almost exclusively apomictic (asexual) seed. Seedlings we have grown from tetraploid maternal plants have produced morphologically uniform populations that appear to be identical to the seed parent. Populations grown from diploid maternal parents clearly segregate to produce morphologically diverse populations. We are currently conducting studies to thoroughly document the extent and completeness of apomixis in various segments of the *Aronia* genus. While polyploid *Aronia* may serve well as paternal parents, they have limited use as maternal parents. Recent European and Russian *Aronia* breeding efforts have made little progress due to their extensive use of polyploidy breeding stock and lack of awareness of apomixis.

ARONIA MITSCHURINII — THE LARGE FRUITED COMMERCIAL CHOKEBERRY

Aronia mitschurinii includes the commercial cultivars ‘Viking’, ‘Nero’, ‘Aron’, and likely all other large-fruited cultivars originating from Europe or Russia. Despite the phenotypic variation amongst wild North American *Aronia* species, none possess morphology closely resembling the plant material used in Eurasian commercial orchards. This has lead to the proposal by Skvortsov and Maitulina (1982) that this phenotype be designated as a fourth species, *A. mitschurinii*. The *A. mitschurinii* phenotype is most similar to *A. melanocarpa* in appearance because both species have black fruits, relatively glossy, glabrous leaves, stems and flowers, but *A. mitschurinii* does possess some unique distinctions from *A. melanocarpa*. Skvortsov and Maitulina (1982) found that *A. mitschurinii* fruits are 1.5-2 times larger than *A. melanocarpa* and possess distinct morphology. Fruits are dull, globular, somewhat depressed at the apex in comparison to wild *A. melanocarpa* fruits which are shiny and oval or pyriform in shape. *Aronia mitschurinii* was also shown to have larger inflorescences, rounder leaf morphology and a faster growth rate than *A. melanocarpa*.

Skvortsov et al. (1983) traced *A. mitschurinii*’s origins back to early 20th century Russia and the research facility of pomologist Ivan Michurin. Michurin focused his research on developing fruit crops suitable for cultivation in Russia. Michurin’s notes describe successful hybridizations between North American *Aronia*, originally received from Germany, native European *Sorbus aucuparia* L., and other members of the subtribe Pyrinae, Rosaceae (Michurin, 1948, 1949).

INTERGENERIC HYBRIDIZATION IN THE *PYRINAE*

The *Pyrinae* base chromosome number is 17 and hybridization between species within genera is common, along with polyploidy, and apogamy (Persson Hovmalm et al., 2004; Campbell et al., 2007). Wide hybridizations and allopolyploidy have been important factors in speciation in the Pyrinae (Campbell et al., 2007; Roberston et al., 2010; Robertson et al., 1991). Robertson et al. (1991) noted reports of 16 genera of Pyrinae involved in intergeneric hybridizations, some of which are highly fertile and occur repeatedly in the wild. *Sorbus* demonstrates a particularly strong ability to partner successfully with many other genera including *Amelanchier* (×*Amelosorbus*), *Aronia* (×*Sorbaronia*), *Cotoneaster* (×*Sorbocotoneaster*), *Crataegus* (×*Crataegosorbus*), and *Pyrus* (×*Sorbopyrus*) (Postman, 2011). Of particular importance to chokeberry breeding are the diploid ×*Sorbaronia dippelii* (*S. aria* × *A. melanocarpa*), ×*Sorbaronia fallax* (*S. aucuparia* × *A. melanocarpa*), and ×*Sorbaronia sorbifolia* (*S. americana* × *A. melanocarpa*).

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T-Budding and Chip Budding at Kankakee Nursery©

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Kankakee Nursery is a family owned and operated wholesale nursery located in Aroma Park Illinois, 60 miles south of Chicago. I am honored to share our production methods with the IPPS here today. My uncle, Phil Worth started budding trees around 1975. In 2013, 34,500 shade and ornamental trees were budded.

Seedlings are purchased from various vendors and shipped to us in February and March. The seedlings are typically 1 year old and are ¼ caliper. The tops and roots are trimmed to prepare the seedlings for planting. Tops and roots are trimmed so that they will fit into the planter. Then they are bundled and palletized until planting.

We typically plow the ground that the understock is planted on in the fall of the previous year. If the soil is lighter a field cultivator can be used. Before planting in the spring, Treflan™ herbicide, a grass preemergent herbicide, is applied at a low rate. No other herbicides are used until fall.

Understock seedlings are the first things planted so they have enough time to get up to size. As always, the weather determines when we can start. Starting dates vary from year to year. For example, in 2012 we started on 9 April and finished 12 April. This year, 2013, we started on 8 May and finished 11 May. The 2-row planter is a mechanical transplanter and is pulled by a 50-hp tractor. The rows are 48 in. apart and plants are spaced either 11 in. or 22 in. within the row depending on whether they will be dug as 1-year whips or 2-year branched trees.

During the growing season the understock field is irrigated and weeded as needed. It is important to keep the seedlings growing so that they are in a vigorous condition when it's time to bud them. The seedlings are prepared for budding by trimming them up from the bottom and scraping the soil away from the base so that the bud is placed low enough.

Budding begins typically on 7 or 8 Aug. and is finished at the end of the month. Depending on the size of the seedling we use either ¼ in. or ⅜-in. rubber strips for T-budding. For chip budding, an elastic plastic tape is used. We use a product called Buddy Tape, made in Japan. Budwood is collected from our stock block as well as from production fields. It is critical that the bud wood is hardened off sufficiently.

In addition to their hourly wage the 3 budders and tiers get 2½ ¢ for each seedling budded as well as another 2½ ¢ for those buds that take. Each budding team will do 900 or 1000 seedlings each day.

In 10 to 14 days the buds knit themselves to the understock. The smaller rubber strips fall off on their own. The larger strips and the tape are removed manually after 3 or 4 weeks.

The trees that we chip bud include *Crateagus*, *Pyrus*, *Quercus*, *Taxodium* and *Ulmus*. Those that are T-budded are *Gleditsia*, *Prunus*, *Malus* and *Tilia*. The determining factor as to what method is used is the size (caliper) of the seedling and how easily the bark separates from the seedling.

After the buds have taken and the strips and tape are off, nothing is done until the following late February and March. At this time the tops are cut off by a tractor mounted stalk chopper. This piece of equipment is used in cattle operations for cutting and chopping silage. The seedling tops are cut at about 6 in. and the wood is chopped and flung through the chute onto the field. A few plants such as elm are too big to be done this way and have to be hauled away. The final cut is made by hand at the proper height and angle.

The next step is to put the Grow Straights down. Grow Straight® stakes were introduced by J. Frank Schmidt and Son nursery in Oregon. It is a metal device designed to eliminate "dog legs". In addition, they also protect the shoots against wind, storms, animals, and other dangers. Also around this time, we fertilize with a granular blend that has urea, diammonium phosphate, and potash. We apply this material over the top with a spreader at 80 to 100 Ibs./acre N.

As the bud grows, it is critical that branching from the understock (suckers) is removed in a timely fashion. These suckers can take energy from the bud and not allow it to reach the proper size. Starting last year we bud the *Malus* on Sproutfree® rootstock. This eliminates the time consuming labor of removing the suckers.

The next step is staking. We use various types of stakes; ½-in. fiberglass, ¼-in. galvanized metal, and bamboo. We are gradually transitioning to all galvanized because of the ease of pushing them into the ground and their flexibility. We use the Max® Tapener tying machine, common throughout the industry.

Insecticide application is done with a John Deere 2955 Hi Boy. The major pests on these trees are leafhoppers. Japanese beetle can occasionally be a problem as well. Increasingly, deer have been a big problem with browsing on *Celtis*, *Ulmus*, and *Crataegus*.

Harvest begins in mid November when the plants have sufficiently hardened off. We have learned through the years that certain types of trees do not keep well for an extended period of cold storage. These trees are dug in late winter or early spring and include *Quercus*, *Ulmus*, and *Pyrus*. Trees are dug with a GK digger.

Softwood Cutting Propagation of Northeast United States Native Shrub Species©

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INTRODUCTION

There is strong consumer interest in native plants for landscaping to create natural gardens that attract wildlife and are not invasive. For growers to capitalize on the native market, they must expand their product lines by adding new species. Landscape plants are often used in locations with challenging environmental conditions including reflected light, high temperatures, inadequate water supply, infertile soil, road salt, and pedestrian pressure. Expanded use of native species will be most successful if growers, landscapers and consumers know which native species will perform well in challenging landscape situations. Research I have conducted at the University of Connecticut has identified underused native shrubs that are adaptable and have the potential to become revenue-generating crops for the nursery industry. Each plant offers gardeners multiple ornamental attributes such as interesting summer foliage, refined habit, edible fruits, attractive flowers, and respectable fall foliage color. These native shrubs have been unused in the landscape because their landscape adaptability was unknown and because production systems have not been developed. Some native shrubs are already being successfully produced by the nursery industry and are widely used in the landscape. Growers must be able to produce these newly identified native shrubs using production systems whose efficiencies are on par with those already used to produce successful native shrubs crops. The goal of the research presented here is to develop commercially viable propagation systems for these novel native shrubs.

METHOD AND RESULTS

During the 2011, 2012, and 2013 growing seasons, propagation by softwood stem cuttings was evaluated for the following native shrub species: *Ceanothus americanus* (New Jersey tea), *Corylus cornuta* (beaked filbert), *Eubotrys racemosa* (sweetbells), *Lonicera canadensis* (American fly honeysuckle), *Myrica gale* (sweet gale), *Prunus pumila* var. *depressa* (creeping sand cherry), *Vaccinium stamineum* (deerberry), *Viburnum acerifolium* (maple leaf viburnum), *Viburnum lantanoides* (hobblebush). Softwood stem material was collected from mature plants and processed into cuttings 10 to 15 cm in length with two to three nodes. Cuttings were wounded and dipped in talc-based, IBA rooting hormone [Hormodin® (OHP Inc., Mainland, Pennsylvania)] at 0 ppm, 1,000 ppm (Hormodin #1), 3,000 ppm (Hormodin #2), or 8,000 ppm (Hormodin #3). Dipped cuttings were inserted into 1.3-L plastic flats filled with medium composed of Canadian sphagnum peat moss, horticultural-grade vermiculite, and horticultural-grade perlite (2:1:1, by vol). Flats of cuttings were held on a polyhouse bench under intermittent mist that provided 10 s of mist every 6 min. After 8 weeks, rooting success was evaluated and the optimal propagation conditions are reported in Table 1.

Table 1. Rooting success.

Native species	Time of year	IBA (ppm)	Rooting (%)
Ceanothus americanus	June	3000	50-60
Corylus cornuta	June, July, Aug.	3000	80-90
Eubotrys racemosa	June, July	0, 1000, 3000	100
Lonicera canadensis	May, June	3000	45-50
Myrica gale	June	3000	90
Prunus pumila var. *depressa*	June, July	3000	90
Vaccinium stamineum	June	1000, 3000	85-90
Viburnum acerifolium[X]	June, July, Aug.	0, 1000, 3000	100
Viburnum acerifolium[Y]	July	3000, 8000	65-80
Viburnum lantanoides	June	3000, 8000	80-85

[X]Two node cuttings.
[Y]Single node cuttings.
Abbreviations: IBA = indole-3-butyric acid.

CONCLUSION

For a native plant to be considered a viable commercial crop for general wholesale nurseries it must be able to be propagated with at least 80% propagation success. Growers focusing on production of only native plant material may find lower percent rooting to be acceptable. *Eubotrys racemosa* and *V. acerifolium*, from cuttings with a minimum of two nodes, were the easiest shrubs to propagate and have the most obvious potential to become mainstream nursery crops. *Myrica gale* and *P. pumila* var. *depressa* were also very easy to propagate from cuttings at commercially viable rates. *Corylus cornuta*, *V. stamineum*, and *V. lantanoides* could be rooted at rates above 80%, and likely can become commercial crops especially if propagation success can be further increased by improving rooting techniques. Without development of improved propagation methods for *C. americanus* and *L. canadensis*, it is unlikely that these two species will be viable crops for large wholesale growers, but may still hold promise for specialty native plant producers. One propagation technique that has proven to be critical in dramatically increasing propagation success with some of the native species (*C. cornuta* and *V. acerifolium*) is overwintering rooted cuttings in their propagation flat and repotting in spring. Leaving cuttings undisturbed for the first overwintering period will likely significantly improve propagation success with other native shrubs species such as *C. americanus* and *L. canadensis*. I am currently conducting container production studies with these native shrub species and others evaluating media properties, fertility and pruning.

New Plant Forum©

Compiled and Moderated by Charles Tubesing

Presenters:

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Acer saccharum 'Morton', Crescendo™ sugar maple
Phlox 'Forever Pink'
Syringa reticulata subsp. *pekinensis* 'Zhang Zhiming', Beijing Gold™ tree lilac

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Deutzia 'NCDX2', Yuki Cherry Blossom™ deutzia ppaf, cbraf
Hydrangea macrophylla 'SMHMTAU', Let's Dance® Blue Jangles™ hydrangea ppaf, cbraf
Ligustrum × *vicaryi* 'KCLX1', Golden Ticket™ ligustrum ppaf, cbraf
Physocarpus opulifolius 'SMPOTW', Tiny Wine™ ninebark ppaf, cbraf
Sambucus racemosa 'SMNSRD4', Lemon Lace™ sambucus ppaf, cbraf

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Aquilegia canadensis 'Pink Lanterns'
Clematis integrifolia 'Blue Ribbons'
Echinacea pallida 'Hula Dancer'
Fatoua villosa
Mirabilis multiflora

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Geum 'Gimlet' PPAF
Geum 'Sea Breeze' PPAF
Vernonia 'Southern Cross'

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Betula nigra 'Dickenson', Northern Tribute® river birch
Picea abies 'Noel', Royal Splendor® Norway spruce
Acer triflorum 'Jack-O-Lantern', Orange Aglo™ threeflower maple

ACER SACCHARUM 'MORTON', CRESCENDO™ SUGAR MAPLE
Selected from the collections of The Morton Arboretum in Lisle, Illinois, for its excellent heat and drought tolerance, durable dark green summer foliage, outstanding orange-red fall color, and uniform, broadly oval habit. Crescendo sugar maple grows to 20 to 25 ft in height with a 15- to 20-ft spread in 10 to 15 years. It is a uniform grower in production. The heavily textured leaves are resistant to leaf tatter in areas of high winds. It makes an excellent specimen or shade tree for the residential lawn, parks, and golf courses. Like other sugar maples, it does not tolerate compacted soils, areas with high air pollution, or significant salt spray or runoff. Consider it as a replacement tree for native ash trees (*Fraxinus* sp.) in areas infested with emerald ash borer. Hardy to U.S.D.A. Zones 4-8. A Chicagoland Grows® Inc., plant introduction.

ACER TRIFLORUM 'JACK-O-LANTERN', ORANGE AGLO™ THREEFLOWER MAPLE
Orange Aglo™ threeflower maple is an outstanding small tree with attractive exfoliating bark coupled with exceptional pumpkin-orange fall color. This species is not common in the nursery trade and propagated by seed resulting in variable fall color ranging from yellow to orange to red, Orange Aglo™ threeflower maple has been selected for consistent orange fall color. This selection has shown superior hardiness as well as no chlorosis symptoms in alkaline pH soils, which is reportedly not typical of the species. Orange Aglo™ has grown approximately 1 ft annually over a 15-year period in the NDSU Research Arboretum. The bark of Orange Aglo™ is noticeable in all seasons and characterized by ash-brown to golden-orange vertical striations. Orange Aglo™ produces quality, trifoliate compound leaves (5.2 in. long and 3.75 in. in width) which are irregularly serrated and semi-pubescent. This is a highly adaptable hardy substitution for paperbark maple (*A. griseum*) in colder climates with its exquisite multi-seasonal effects. Uses for this outstanding small size tree are many, including specimen, residential landscape, parks and public grounds especially with featuring the ornamental bark and quality foliage. Propagation is not easy grafting is recommended. USDA Hardiness Zone 3.

***AQUILEGIA CANADENSIS* 'PINK LANTERNS'**

The Canada columbine has a wide natural distribution from cold areas of Southern Canada, and the Northern USA, to the hot and humid summer parts of the Southeastern USA, and across the Great Plains of the Central USA. It is one of the most durable columbines. The North American species can be found in dry woods, rock ledges and peat bogs. It has been in cultivation since 1640 and the American Indians allegedly used Canada columbine to prepare a "love" potion.

'Pink Lanterns' has dainty, curving short-spurred, nodding pink blooms – with straw-colored inner petals – that rise 45 cm (18 in.) on wiry stems above basal rosettes with handsome, three-lobed leaves. Plants are hardy in Zones 3-8.

We are honored that the lovely Dyck Arboretum of the Plains in Hesston, Kansas would share this wonderful pink-flowering seed strain with Jelitto Perennial Seeds.

***BETULA NIGRA* 'DICKENSON', NORTHERN TRIBUTE® RIVER BIRCH**

An outstanding landscape specimen with its upright rounded habit and ivory bark exfoliating to copper-bronze. Northern Tribute® has shown superior adaptability to stresses of the upper Midwest and Northern Plains. It has shown no signs of winter injury or iron chlorosis in alkaline soils and has performed well in compacted, dry soils, which is extremely atypical of the species and other selected cultivars. Northern Tribute®'s abilities to perform well in compacted, dry soils will greatly open the landscape possibilities of this species even in warmer hardiness zones. Summer foliage is lustrous medium to dark green with outstanding golden yellow fall color. Prefers moist well-drained soil but performs well in compacted, dry soils. It is pH tolerant including alkaline soils. It is recommended as a landscape specimen tree in more open areas. Most cultivars of river birch suffer winter injury in Zone 3 and suffer from iron chlorosis in alkaline pH soils; Northern Tribute® has shown no signs of winter injury or iron chlorosis in alkaline soils. USDA Hardiness Zone 3.

***CLEMATIS INTEGRIFOLIA* 'BLUE RIBBONS'**

'Blue Ribbons' is an improved, low-growing seed strain with an abundance of 4.5 cm (1.75 in.) flowers that are up to 3 times bigger than typical forms. Jelitto's 'Blue Ribbons' remains upright to 40 cm (16 in.) and doesn't sprawl like others, though light staking or support of other perennials is still helpful where heavy summer rains or high winds prevail.

The nodding, indigo blue flowers, shaped like little parasols, flower from May through August and are followed by decorative silvery seed heads into early winter. 'Blue Ribbons' grows wider and more beautiful every year, and is a wonderful new selection of a long-lived species that deserves wider use.

***DEUTZIA* 'NCDX2', YUKI CHERRY BLOSSOM™ DEUTZIA PPAF, CBRAF**

- First ever Nikko-type with pink flowers
- Developed by Dr. Tom Ranney of North Carolina State University
- 12-24 in. tall. Great for mass planting
- Deer resistant
- USDA 5, AHS 8
- Sun/part shade

ECHINACEA PALLIDA ‘HULA DANCER’

The low maintenance and drought tolerant *E. pallida* grows primarily in sunny, rocky sites in the eastern portions of the prairies of the Great Plains in the United States. It is the only coneflower species with white pollen. This Jelitto seed strain evokes a dancer at a traditional Hawaiian luau in spite of the fact that it is actually a tough prairie coneflower. The dramatically reflexed, very narrow, white petals with a pink tinge, drooping from orange-brown cones conjure images of swaying dancers and south Pacific breezes.

The blooms are slightly fragrant, attract butterflies and would be a nice addition to a cut flower arrangement. Elegant ‘Hula Dancer’ grows on single, unbranched slender stems to 80 cm (32 in.) and is perfectly cold hardy to -25°C (-20°F). ‘Hula Dancer’, is as much at home in the garden as it would be on the prairie.

FATOUA VILLOSA

There are weeds of annoyance and weeds of perpetual affection. My garden is carpet bombed with seeds of red buds *Cercis canadensis,* the Eastern redbud. I put up with them, the same as I did my children when they were annoying teenagers.

Mulberry weed is an unwelcome guest that I can’t shake loose. The trouble is: the mulberry weed doesn’t travel alone. I’d like to get rid of them all, but there is no end to mulberry weed. In a prodigious year for weeds in Kentucky, I fear *F. villosa* is winning the war.

The rogue showed up in my Louisville garden 7 or 8 years ago and never takes a day off from May until frost. It is usually easy to spot, growing upright to a foot or more, but there are wayward progeny with procumbent growth, creeping low-slung, in the semi-shade. These are the hardest to nab. This mulberry tree relative has dull, barely distinguishable flowers that produce mature seeds in the blink of an eye. A gazillion seeds give or take can be catapulted across two time zones.

GEUM 'GIMLET' PPAF, AVENS OR GRECIAN ROSE

An Intrinsic Introduction. This light yellow *Geum* can have white tips in its petals especially as the semi-double flowers fade. They begin blooming in early May and continue for 3-4 weeks on 18 in. green stems. Full sun, rich moist soil is best.

GEUM 'SEA BREEZE' PPAF, AVENS OR GRECIAN ROSE
An Intrinsic Introduction. This robust grower has larger hairy foliage than most *Geum* introductions. Orange flowers can verge on the red side after cold nights and measure 2 in. wide. The unique flowers have folded wavy petals like they are blowing in the breeze and are held on red 18 in. plus stems. Full sun, rich moist soil. Nice with salvias.

HYDRANGEA MACROPHYLLA **SMHMTAU, LET'S DANCE® BLUE JANGLES™ HYDRANGEA PPAF, CBRAF**
- Compact habit
- Strong rebloomer
- Pure blue or pink mophead
- Most intense blue color
- Sturdy stems
- 2-3 ft tall
- USDA 5, AHS 9
- Sun/part shade

***LIGUSTRUM* × *VICARYI* KCLX1, GOLDEN TICKET™ LIGUSTRUM PPAF, CBRAF**

- Sterile golden vicary privet
- Heavy, sweet fragrance
- Glossy, golden foliage
- Compact habit
- Easy to grow
- 4-6 ft tall
- Deer resistant
- USDA 5, AHS 10
- Sun

MIRABILIS MULTIFLORA

The Colorado four o'clock is a durable perennial that has a native range from Colorado, south to Texas and west to California. The species grows to 60 cm (24 in.) and has ovate, gray-green foliage and rose-purple blooms that open at dusk and close in the early morning hours. I've grown the drought resistant species in a well drained, gravel bed in Kentucky in full sun for 6 years.

NYSSA SYLVATICA **'WFH1', TUPELO TOWER™ BLACK TUPELO PP22976**
Zone 4-9, height: 30-40 ft , width: 12-15 ft

Tupelo Tower™ black tupelo is a unique and distinctive upright tree with ascending branches and central leader that gives it a strong vertical habit. The leaves are dark green in summer turning to shades of gold and orange in the fall. Small blue fruit are taken by the birds in mid autumn. Useful as a street tree or upright specimen. Adaptable to a wide range of soil. Selected as a seedling from native trees in northeast Ohio. Introduced by Klyn Nurseries of Perry, Ohio. Introduced year: 2013.

***PHLOX* ‘FOREVER PINK’**
Compact, carefree, and long-blooming, *Phlox* ‘Forever Pink’ is destined to be a popular garden plant. This beautiful selection is covered with vibrant purplish-pink flowers for three weeks in late May into June in northern Illinois (U.S.D.A. Zone 5a), then repeat-blooms well into October, truly living up to its name. It appears to be sterile, which would explain its long bloom season. Plants are compact, dense, and remain upright all season, growing to 13 in. tall in foliage, 16 in. tall in bloom and 18 in. wide. The foliage is quite resistant to powdery mildew. Use this striking selection in full sun toward the front or middle of the perennial border. Take advantage of this phlox’s uniform size and mass the plants for a striking display. Selected in 2009 from a hybrid cross made at the Chicago Botanic Garden in 2007. Hardy to U.S.D.A. Zones 4-8. Easy to propagate from cuttings. A Chicagoland Grows® Inc., plant introduction.

PHYSOCARPUS OPULIFOLIUS **'SMPOTW' TINY WINE™ NINEBARK PPAF, CBRAF**

- Dwarf hybrid smaller than other red-leaved ninebarks
- Mildew resistant
- Extra bushy with small, refined leaves
- Deep bronze-maroon foliage with white flowers in late spring
- Great for cut flowers
- USDA 3, AHS 7
- Sun

***PICEA ABIES* 'NOEL', ROYAL SPLENDOR® NORWAY SPRUCE**
Royal Splendor® is a striking evergreen landscape specimen characterized by a narrower, upsweeping branch angle with brighter emerald-green needle color. It has an outstanding narrowly-pyramidal habit devoid of drooping, pendulous tertiary branchlets, which typify this species. Mature size is 40 ft × 25 ft. Performs best in well-drained soil and is tolerant of higher pH soils. It is recommended as a landscape specimen tree in more open areas or as a nice upright screening tree. Royal Splendor® Norway spruce is deer resistant and stigmina needle cast disease resistant making it superior over other spruce selections. This is not the typical Norway spruce to hide in a windbreak. Royal Splendor® Norway spruce is typically side grafted. USDA Hardiness Zones 3.

***SAMBUCUS RACEMOSA* 'SMNSRD4', LEMON LACE™ SAMBUCUS PPAF, CBRAF**
• Lacy golden foliage with red new growth
• Improved sunburn resistance
• White spring flowers and red fruit in fall
• Foliage more deeply cut than 'Sutherland Gold' or Black Lace™ sambucus
• Tolerates full sun in northern climates; prefers light shade in southern areas
• 3-5 ft tall
• Deer resistant
• USDA 3, AHS 7
• Sun/part shade

***SYRINGA RETICULATE* SUBSP. *PEKINENSIS* 'ZHANG ZHIMING', BEIJING GOLD™ TREE LILAC**

This selection exhibits multiple seasons of interest, from its panicles of fragrant, primrose-yellow flowers in early summer to its dark green foliage that can turn an eye-catching yellow in autumn. The ornamental, cherry-like cinnamon-colored bark is attractive year-round. Beijing Gold™ tree lilac grows to 20 ft in height with a 15-ft spread. It is more upright and less coarsely branched than most other tree lilacs. This selection was made by Zhang Zhiming of the Beijing Botanic Garden, People's Republic of China, and introduced into the United States through the North America-China Plant Exploration Consortium (NACPEC) and The Morton Arboretum. Excellent as a specimen plant or in groups in the lawn or along drives and parkways, in the mixed woody plant border, as a foundation shrub, or in any other suitable habitat where its attributes can be appreciated year-round. Hardy to U.S.D.A. Zones 4-7. A Chicagoland Grows® Inc., plant introduction.

VERNONIA 'SOUTHERN CROSS', IRONWEED
An Intrinsic Introduction. A favorite selection this hybrid came from seed sown as *V. lettermanii*. The other parent is unknown but it had broad foliage and this one has intermediate foliage measuring up to ½ in. wide. The deep green foliage looks good all season long. The plant grows 3 ft tall and wide, blooming in August. Purple flowers can have thin white filaments along with lacy purple petals that emerge from deep purple buds that look like little jewels.

How Plant Hormones Work – Auxin©

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INTRODUCTION

Plant hormones (also phytohormones) are naturally occurring organic chemicals that are active in low concentrations. The traditional definition of a hormone is that they are synthesized at one location and translocated to their site of action. However, there are some exceptions for plant hormones. The five major plant hormones are auxin, cytokinin, gibberellin, abscisic acid, and ethylene. Additional compounds considered plant hormones include brassinosteroids, jasmonic acid, salicylic acid, and polyamines. Plant hormones are important to propagation because they act endogenously to regulate plant function and can be applied to induce specific responses such as root initiation in cuttings and dormancy release in seeds (Hartmann et al., 2011).

It is beyond the scope of this paper to describe all the actions for each of the plant hormones, but because of the importance of auxin to plant propagation, it will serve as the example for hormone action. Therefore, the objective of this paper is to provide some background for the use of auxin in cutting propagation and then describe the advances in hormone action that relate to the control of adventitious root initiation.

HISTORICAL BACKGROUND

Fritz Went (1928) building on the initial research of Charles Darwin (Darwin and Darwin, 1880) and Boysen Jensen (1911) developed the first bioassay for detecting hormones in plants based on the bending of grass and oat seedlings to light. Went placed agar blocks containing suspected hormones asymmetrically on decapitated oat seedlings and measured the bending of the coleoptile. Kögl and Haagen-Smit, between 1933 and 1935, found that substances in human urine and various plant extracts that were active in Went's coleoptile bioassay. This led to the chemical isolation of "heteroauxin" [indole-3-acetic acid (IAA)] identified as the first plant hormone. Soon after this, Went (1934) developed another bioassay based on the discovery that auxin-induced adventitious roots in etiolated pea cuttings. Fischnich (1935) showed that applied IAA could induce adventitious roots to form on intact coleus (*Solenostemon*) stems. Possibly, the first specific report of IAA being used to stimulate rooting in cuttings was by Cooper (1935). He applied IAA in lanolin paste to stimulate rooting in lemon (*Citrus*), lantana (*Lantana*), and chenille plant (*Acalypha*) stem cuttings. By 1935, synthetic auxins were developed that were shown to promote rooting in cuttings (Thimann, 1935; Zimmerman and Wilcoxon, 1935). These included the familiar α-naphthaleneacetic acid (NAA) and indolebutyric acid (IBA) compounds used by modern propagators.

The potential commercial importance of auxin to cutting propagation was almost immediate. By 1935, researchers at the Boyce Thompson Institute showed the efficacy of auxin in stimulating rooting in cuttings of over 85 genera of plants, including woody plants that had proven too difficult to propagate in the past (Zimmerman, 1935). The Boyce Thompson Institute was granted a patent for use of these synthetic auxins and subsequently licensed Merck and company (New Jersey) to distribute Hormodin A for commercial application. By 1947, four commercial companies were offering synthetic auxin formulations in talc for application to cuttings. Along with Merck's Hormodin formulation, they were Quick-Root from Dow Chemical, Rootone from American Chemical Paint Co., and StimRoot from Plant Products Co. (Avery et al., 1947).

Initially cuttings were treated by prolonged (24 h) soaks in aqueous auxin solutions. Grace in 1937, developed the method of incorporating auxin in talc to deliver auxin to cuttings that would eventually become the standard commercially. The quick-dip method for treating auxin was developed by Hitchcock and Zimmerman in 1939 and later refined by Cooper in 1944. In an excellent review of research in cutting propagation by Avery and Johnson (1947), they provide a table with references on experimental rooting for over 600 different kinds of woody plants. This provides a wonderful overview of the impact of auxin on rooting cuttings in the era prior to the use of mist by the greenhouse and nursery industry.

AUXIN BIOSYNTHESIS AND MOVEMENT

There are two biosynthetic pathways for IAA in plants (Benjamins and Scheres, 2008). Primary auxin biosynthesis is via the amino acid L-tryptophan, but IAA can also be synthesized by a tryptophan-independent pathway. Most of the IAA in plant tissue is in the conjugated form using both amino acids and sugars for conjugation. Primary sites of auxin biosynthesis include root and shoot meristems, young leaf primordia, vascular tissue, and reproductive organs including developing seeds.

Auxin movement from cell to cell requires efflux carriers located on the plant membrane (Peer et al., 2011; Woodward and Bartel, 2005). They control polar auxin movement from plant tips (distal ends) to their base (proximal end). Auxin movement and the subsequent polar gradient established between cells is important for normal plant development. The auxin source in untreated stem cuttings is the shoot tips and polar movement of this auxin allows accumulation at the base of the cutting where rooting occurs.

Indole-3-acetic acid degrades in the light and exogenously applied IAA is quickly degraded by the enzyme IAA-oxidase. Synthetic auxins are less susceptible to enzyme degradation and are therefore used more often for commercial applications. The most often used auxins are derivatives of indole-3-butyric acid (IBA) and α-naphthalene acetic acid (NAA). Auxins are not readily dissolved in water and must be dissolved in a solvent (ethanol, DMSO) or a base (1N NaOH) before being quickly added to water. Potassium salts of IBA and NAA (K-IBA, K-NAA) are auxin formulations that are water soluble and available commercially. Auxin application for cuttings can be at the base of the cutting as a low concentration dilute soak or higher concentration quick dip. Alternatively, auxin can be foliar applied as a spray (Hartmann et al., 2011).

AUXIN-INDUCED ROOT FORMATION

As described previously, auxin can induce adventitious rooting in cuttings in a wide distribution of species. However, there are cuttings from some plant species that do not respond to auxin to promote adventitious rooting. These cuttings are termed difficult-to-root and auxin non-responsive. For many years, researchers have been searching for biochemical substances that in addition to auxin would promote rooting in this group of cuttings. This refers to a theory of root induction that ascribes to a strictly biochemical basis for rooting. This theory implies that there are root-promoting and root-inhibiting substances produced in plants and their interaction is thought to control rooting. Therefore, difficult-to-root cuttings either lack the appropriate root-promoting substances or are high in root-inhibiting substances. This theory has a long historical foundation, but has yet to yield important information on these elusive compounds.

The initial concept for substances initiating root formation in plants comes from the pioneering German plant physiologist, Julius Sachs in the1880s. He felt that there were specific chemical plant morphogens responsible for directing growth and development including root formation (Sachs, 1880). Fritz Went in 1938, postulated that root forming substances made in the leaves moved to the base of cuttings and were involved in adventitious root formation. He termed this substance(s) rhizocaline.

In an elegant study in 1946, Van Overbeek et al. reported that grafts between easy and difficult-to-root cultivars of rose-of-Sharon (*Hibiscus rosa-sinensis*) resulted in a graft transmission of a substance from the easy-to-root cultivar that improved rooting in the difficult-to-root cultivar. In 1959, Charles Hess detected "rooting cofactors" from extracts of the juvenile form of English ivy (*Hedera helix*) as indicated by increased root formation in the mung bean (*Phaseolus aureus*) bioassay. The chemical nature of rhizocaline has never been elucidated and the physiological relevance of graft transmissible rooting factors and rooting cofactors has been challenged (Hartmann et al., 2011). It appears that there is a fundamental difference between a cell's competency to respond to auxin between easy and difficult-to-root phases of a plant's life cycle that requires gene expression experiments to elucidate. However, the importance of buds and leaves for rooting in some species and other interesting cofactor studies still hint at the existence of the illusive rhizocaline.

MOLECULAR BASIS FOR ROOTING

There are few studies that describe auxin-induced gene activity during critical phases of the adventitious rooting process. However, it is clear from global gene expression experiments that there is a suite of new gene expression that is induced during the root initiation process (Brinker et al., 2004; Wei et al., 2013). Considerable progress has been made in the past 5 years on the molecular perception and gene activation following auxin treatment.

A common mechanism for auxin-induced gene activity is outlined in Figure 1 (Chapman and Estelle, 2009). It is common for auxin-inducible genes to be repressed (prevented from action) by the protein-protein interaction the Aux/IAA repressor molecule acting on the Auxin Response Factor (ARF) positioned in the promoter region of an auxin-inducible gene (Fig. 1A). In order to activate the gene, the repressor molecule (Aux/IAA) must be removed from its interaction with ARF. In order for this to occur, auxin (IAA) must interact with its receptor complex (Fig. 1B). The auxin receptor is the F-box protein TIR1 located in the cell's nucleus. There are several proteins that associate with TIR1 to form a receptor complex. The job of the receptor complex is to locate Aux/IAA and to attach several ubiquitin molecules to the protein (Fig. 1C). This poly-ubiquitination targets Aux/IAA for proteolytic destruction. Once Aux/IAA is removed from association with ARF, it acts to initiate gene transcription of the auxin-inducible gene.

It is evident from this discussion that Auxin Response Factors are important for initiating an auxin response. Recently, the ARFs important for adventitious root formation have been found in *Arabidopsis*. They include ARF6, ARF8, and ARF16. Additional research has shown that the level of these ARFs is under translational control by microRNAs. A microRNA (Fig. 2A) is a small regulatory RNA consisting of 22 nucleotides (Meng et al., 2011). The sequence of these nucleotides related to auxin-induced gene expression corresponds to a section of the coding region of the mRNA for ARF. If a specific microRNA corresponding to an ARF is produced, it will prevent or considerably reduce the production of the ARF protein (Fig. 2B). In *Arabidopsis*, the microRNAs responsible for ARF levels are miRNA 160 and miRNA 167 (Gutierrez et al., 2009).

Therefore, it is becoming evident that for a cutting (at least in *Arabidopsis*) to be competent to form adventitious roots, there must be available auxin to interact with its receptor complex as well as the production of specific Auxin Response Factors to initiate gene expression. Although, this research is yet to be accomplished, it is logical to hypothesize that one possible reason difficult-to-root, non-auxin responsive cuttings fail to root is that they fail to produce appropriate ARFs. It is also logical to assume that the deficiency in ARF production is likely due in part to gene silencing by microRNAs.

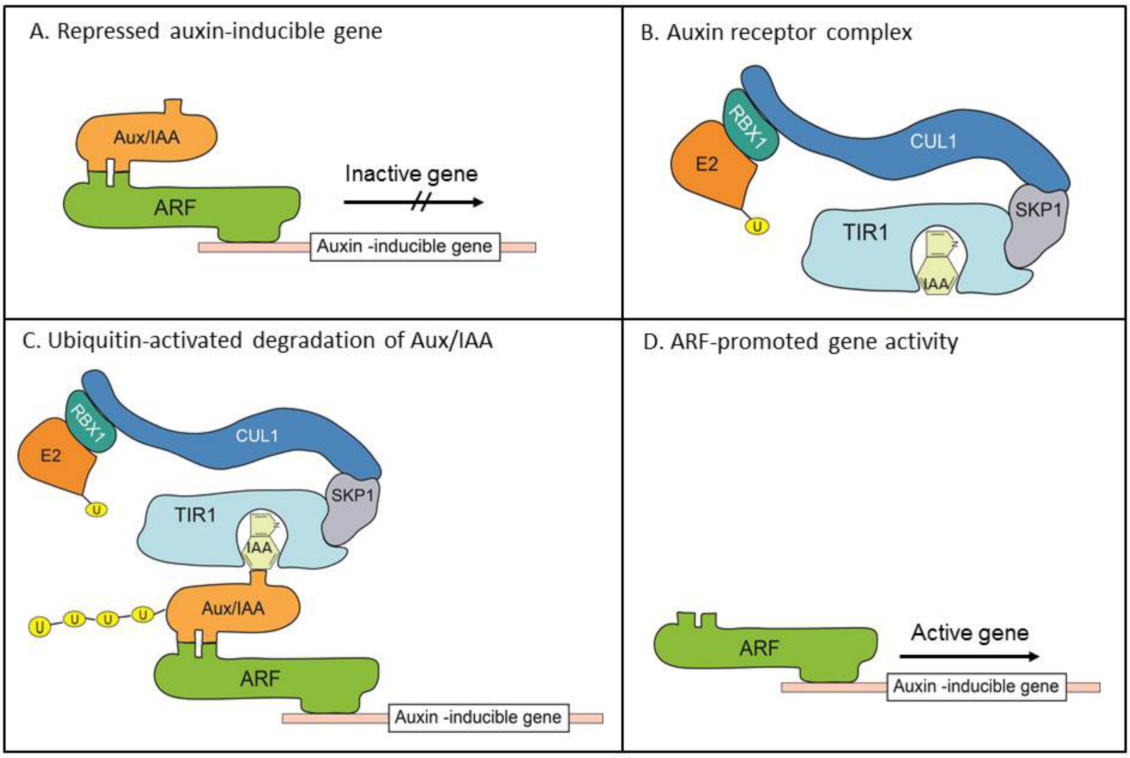

Fig. 1. Steps in auxin perception and gene activation. ARF is an auxin response factor; Aux/IAA is a transcription factor repressor; TIR1 is the auxin receptor.

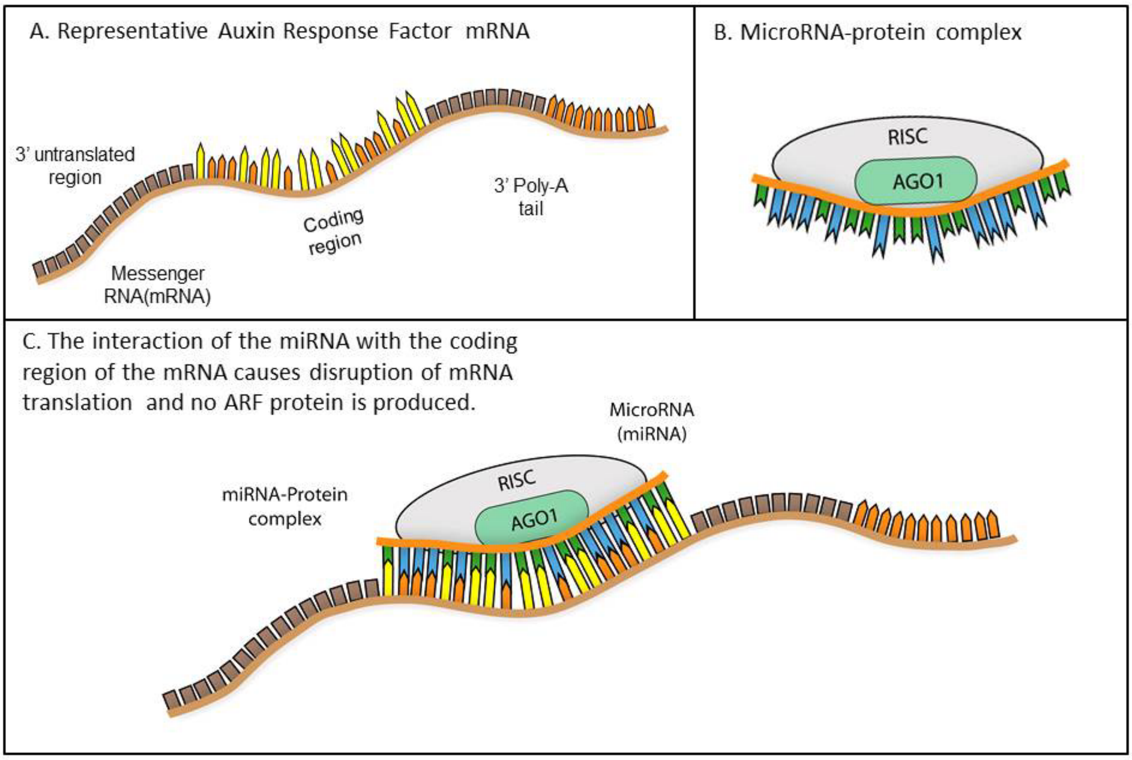

Fig. 2. Representation of translational control of an Auxin Response Factor production by microRNA.

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Willoway Nurseries Production©

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Willoway Nurseries was founded in 1954 by Les and Marilyn Demaline. Although in the early days it was geared more towards a landscape nursery the owners always produced some of their own material. As (son) Tom and (daughter) Cathy grew older and they became more active in the business (now a wholesale nursery), more emphasis was placed on propagation and producing in house liners.

Personally, I started in March of 1980. Currently, my primary responsibility would be the management of the main container farm in Avon, Ohio. This consists of 100+ acres of container stock. Although I'm not directly involved with propagation I have a major impact on what the greenhouse department does for cuttings through the scheduling of maintenance and production of the cutting stock (salable inventory).

Back in the early days the propagation crew would go out with a list, find the plants, take the cuttings, strip, and stick the cuttings. If the plants were trimmed, sold or not big enough the cuttings would have to be taken at a later date, if at all. Using our own mix, we would fill individual peat pots and put them in flats. One of the first major improvements was getting sheets of peat pots that could be placed directly into the flat. Although initially filled by hand, these flat/insert combos are now filled by machine.

We have always tried to produce the majority (85% or more) of our own liner material. Currently we are taking over 3 million softwood cuttings. As one can imagine this can lead to some major problems in scheduling of work for all the departments involved in the plant production process.

Over the years we have accumulated records of when it was the best time to take the cuttings. With some plants it didn't matter as to when the cutting was taken. Some of the more difficult plants were based on a date as to when to evaluate the cuttings. These plants would take precedence over the other cuttings scheduled in that time frame. We have looked at tying the stick date to degree days but have found that the 2 week window we currently use works just as well. The other issue tied to the stick date was getting cuttings done early enough to meet the production schedules that we have set.

Due to the fact that a lot of things were remembered by several key people it was decided to use a database (FileMaker®) to form a "recipe card "to produce the plant. It was set up similar to a note card system (Fig. 1). The demo that you will see has evolved over time. Just like everything else we have adapted and changed to create something that gives us what we want or what we think we want at that point in time. We were fortunate to have Dan White to oversee the FileMaker system. He has done all of the custom work we've requested over the years.

With the FileMaker system a production card was formed that created the recipe for producing the crops (Fig. 1). The first line in the instruction was set up to read BUY or STICK. If it was a liner that was to be purchased (BUY) — it would then have a date placed on it as to when the best time was to place the order. This information would then go into the purchasing module and the information would be shared between the cards. The same thing would occur in the STICK mode (Fig. 2). This would have a date (1st or the 15th of the month) as to when the plant would be stuck. On the grower card the rest of the information would pertain only to the production of the plant.

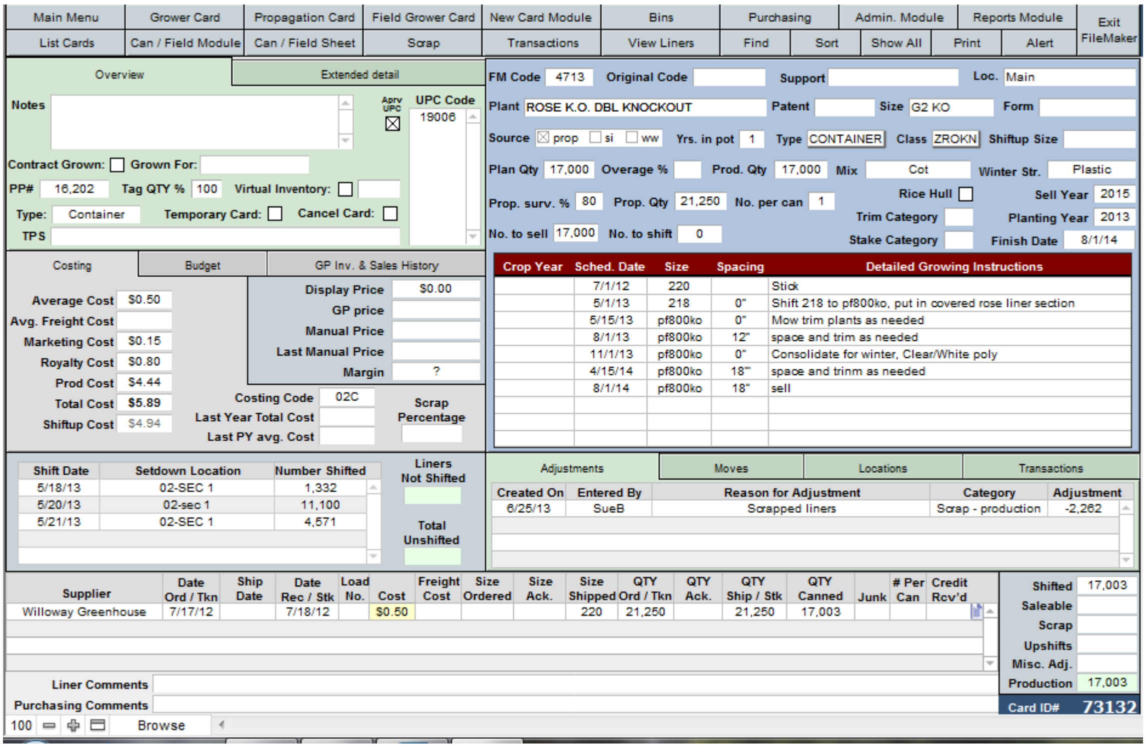


Fig. 1. FileMaker system and a typical production card for producing a particular plant.

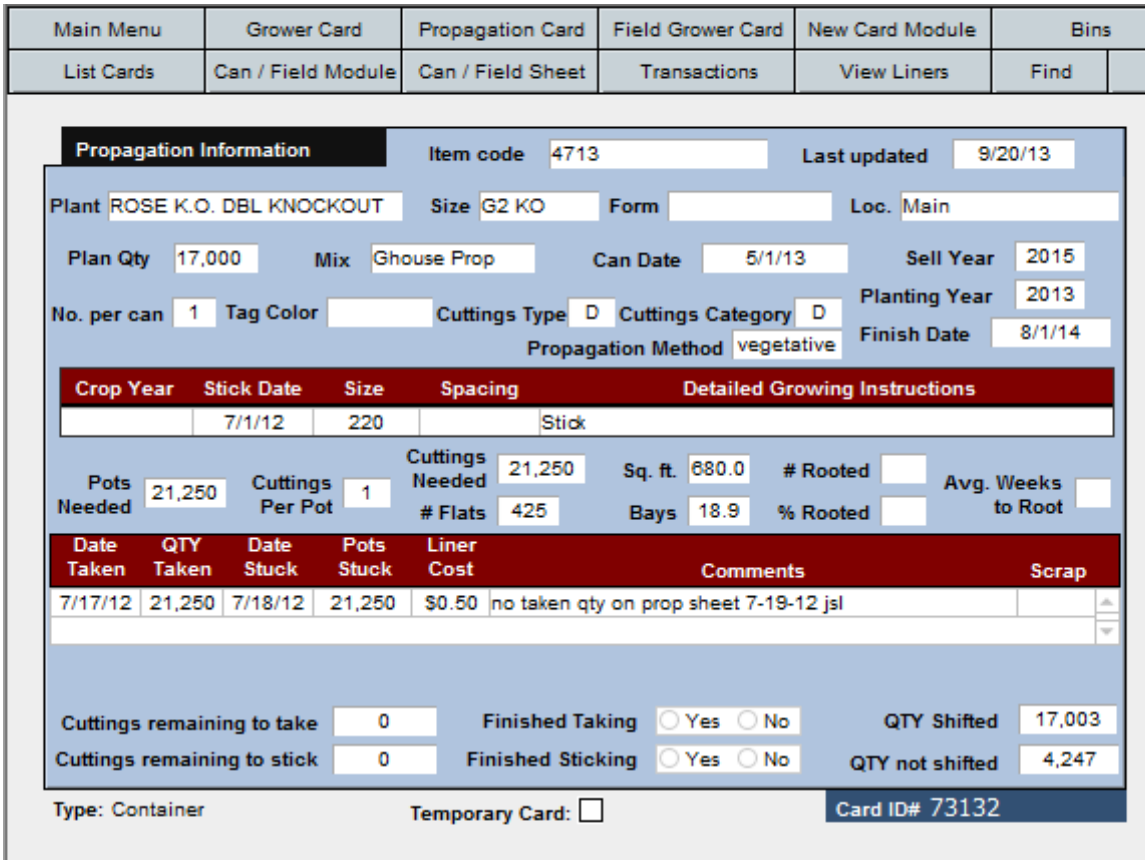


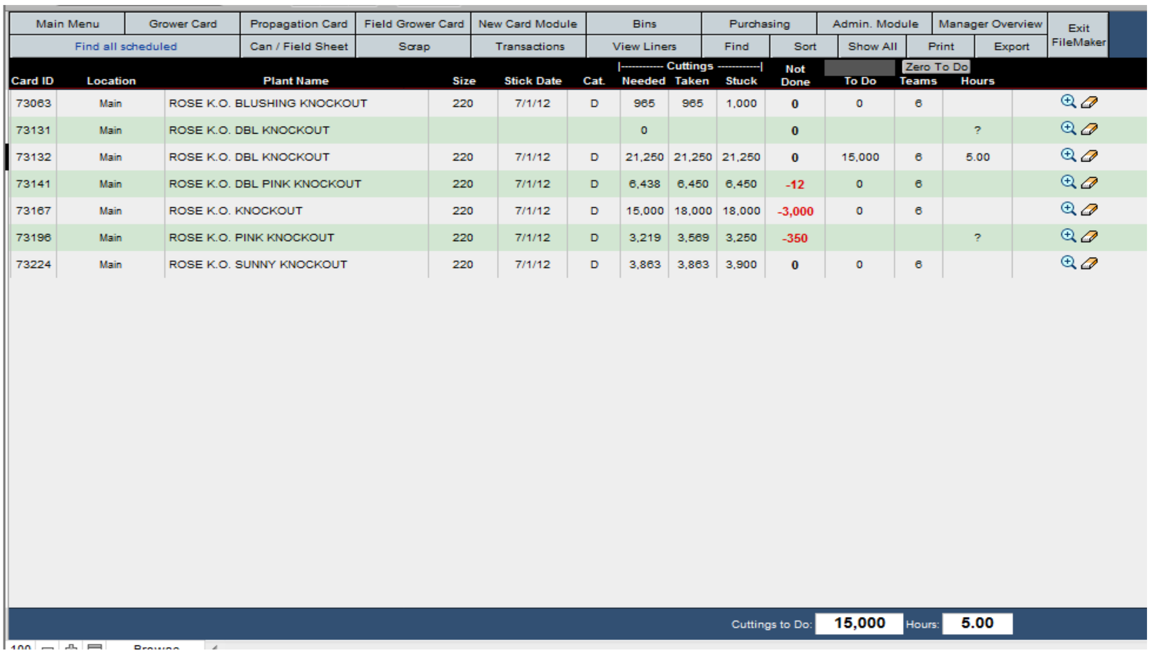
Fig. 2. Information for the STICK mode.

Although we now had a timeline within which to schedule our cuttings we invariably loaded the 2-week windows with too much material and the greenhouse department would not be able to complete the job. This would lead to major issues with the production departments as we would try and schedule trimming around the needs for the cuttings. We could only hold back the trimming for so long and then there would be no cuttings when the propagation crews needed the cuttings.

As we tried to become more efficient we did a Kaizen (Japanese for “improvement” or “change for the best”, refers to philosophy or practices that focus upon continuous improvement of processes) on the greenhouse propagation line. This line was installed when the new Huron greenhouse structure was built. It’s an Agronomix line with multiple stations for the crews to stick cuttings at. It was decided that groups of three people were the ideal set up for the sticking line. A “runner” was set up to take the flats of cuttings into the greenhouse on racks pulled by an electric cart. The flats were set down on the floor and the booms were set up to mist. Another runner kept the soil line full and provided the cuttings for the crews sticking. This set up a continuous flow pattern.

A board was set up by the machine with the amount of flats that need to be produced for the day. Cuttings were split up by different types and time was allocated to the types (2/peat pot, rose/barberry, etc.). All this was then tied together to establish the information we use to schedule the cuttings now. We’ve done this the past 2 years and have been able to keep better tabs on what is getting done and if we are staying on track with our expectations. We can also better monitor how long the cuttings are staying in the cooler.

With all the data accumulated and in place in FileMaker, we schedule a meeting between the Avon farm manager (me) and the Huron farm manager (Dave Geary) as well as Tom. We will scroll through the list of plants for the time frame we are in and put the cutting numbers in place. Early in the season there will be seven crews sticking. We can add or take away from that as the crew number changes. The system will automatically calculate the number of man hours needed to complete that particular crop we have scheduled. A total will appear at the bottom of the sheet and we will keep a running tab (manual) of the number of hours we have used. We will usually go 5-10% over so that there is no need for an emergency scramble in the middle/end of the week.


Main Menu | Grower Card | Propagation Card | Field Grower Card | New Card Module | Bins | Purchasing | Admin. Module | Manager Overview | Exit FileMaker
Find all scheduled | Can / Field Sheet | Scrap | Transactions | View Liners | Find | Sort | Show All | Print | Export

Card ID	Location	Plant Name	Size	Stick Date	Cat.	Cuttings Needed	Cuttings Taken	Cuttings Stuck	Not Done	To Do	Teams	Hours
73063	Main	ROSE K.O. BLUSHING KNOCKOUT	220	7/1/12	D	965	965	1,000	0	0	6	
73131	Main	ROSE K.O. DBL KNOCKOUT				0			0			?
73132	Main	ROSE K.O. DBL KNOCKOUT	220	7/1/12	D	21,250	21,250	21,250	0	15,000	6	5.00
73141	Main	ROSE K.O. DBL PINK KNOCKOUT	220	7/1/12	D	6,438	6,450	6,450	-12	0	6	
73167	Main	ROSE K.O. KNOCKOUT	220	7/1/12	D	15,000	18,000	18,000	-3,000	0	6	
73196	Main	ROSE K.O. PINK KNOCKOUT	220	7/1/12	D	3,219	3,569	3,250	-350			?
73224	Main	ROSE K.O. SUNNY KNOCKOUT	220	7/1/12	D	3,863	3,863	3,900	0	0	6	

Zero To Do
Cuttings to Do: 15,000 Hours: 5.00

Fig. 3. Example of partial numbers entered for a crop.

Through the course of the summer we will continue to meet until the summer softwood cuttings are done. We can enter partial numbers when needed (Fig. 3). This may occur on new items or if we don't feel we have enough cuttings available to complete the project. If we run ahead of schedule or we feel we have other crops ready we will move them forward. Unlike previous schedules we would come up with we now know when we have to stop to allow the propagation department enough time to stay ahead. This has helped all departments to better plan and schedule their work.

We are currently producing 3 million cuttings each year and sticking 25,000-30,000/day. This is done with 6-7 groups of three people and the use of two runners. One runner takes care of soil and providing cuttings for the 6-7 groups sticking and one will deal with the set down. Five people take the cuttings to supply the groups — they may assist on the "inside" if they get ahead of the sticking groups.

Grafting for Quick Turn – Bigger Can Be Better©

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Klyn Nurseries produces a wide range of plant material serving the landscape industry in Ohio and surrounding states. Customers include landscape contractors, municipalities, and rewholesalers with a minimal focus on the garden center market.

To this end we produce a diverse range of plant material both in containers and in the field. We already were doing most of our own propagating by soft and hardwood cuttings, root cuttings, seed, divisions and had developed a successful bed system for developing a sizeable liner as well as finished size boxwood and other plants for B&B or to containerize. We look on the open market to find the unusual plants we are interested in producing as well as sources of liners for plants we find difficult to produce internally.

We did not have a grafting program and had to locate all grafted liners. We had a 30 ft × 100 ft polyhouse with bottom heat we were using for summer propagation of softwood cuttings but were using for minimum heat overwintering in winter. The individual managing our bed production had abilities with budding that we were choosing not to use because he was too busy managing the 15 acres of beds through the growing season but had little to do in the winter months.

In January of 1999 and again in 2000 I sent him to help a conifer grafter to learn how to graft and paid him to work for "free." He learned quickly grafting small evergreen scions on seedling understock in tree bands using a side veneer graft. He saw how a great number of plants could be produced by this method in a limited amount of space for sale as liners, but that the resulting plants were of a small size adding time to grow a finished product.

What we needed was a grafting program of 7-10 thousand large liners for internal production not mass produced grafts for sale as liners. We evaluated what would be the most important plants for us to produce. This included many plants grown as standards and others that are expensive as liners as well as plants that were difficult to find including some of our own selections. We had good sources for most of our grafted conifers. We also considered that we would need different conditions for most conifers and deciduous plants.

Some of the plants we chose to produce include: forms of *Acer palmatum*, *Asimina triloba*, *Carpinus*, *Cercidiphyllum*, *Cornus*, *Crataegus*, *Fagus*, *Ginkgo*, *Hamamelis*, *Koelreutaria*, *Larix*, *Liquidambar*, *Liriodendron*, *Magnolia*, *Metasequoia*, *Nyssa*, *Quercus*, *Taxodium*, *Sophora*, *Zelkova* and a wide range of standards of many genera and species.

Today we produce most of our own understock. Understock for most standards such as *Viburnum*, *Cotoneaster*, and *Syringa* are grown in 1- and 2-gal containers to produce straight and vigorous plants. *Carpinus*, *Nyssa*, *Metasequoia*, *Taxodium*, and others are produced in 2-gal containers as part of our potted tree-liner program (Figs. 1 and 2).

Fig. 1. Grafting understock fall 2013.

Fig. 2. *Parrotia persica* ‘Pendual’ (left).

The understock is assembled outside of the grafting house in November and allowed to stay outside through December to chill. From late December through early January plants are brought into the greenhouse and staged on the heated floor at 58-60°F. Most understock needs some root activity before grafting. Some plants such as *Syringa*, *Metasequoia* and *Quercus* can be brought in later and grafted fully dormant. Once plants are staged the bottom heat is turned up to 68-70°F to initiate root activity while air temperature is kept cool to keep the tops dormant. Four horizontal flow fans keep the air moving and the area is kept clean to keep disease from developing. The house is vented when weather is appropriate.

Plants such as *Fagus* and *Hamamelis* are stage on the cooler north side of the house while *Malus*, *Syringa*, and *Viburnum* are situated to take advantage of a warming winter sun.

Juniper hetzi is used as understock for *Cupressus nootkatensis* (syns. *Chamaecyparis nootkatensis* and *Xanthsoyparis nootkatensis*) cultivars and can be grafted as early as November and as late as early March as it is easy to get the roots active.

We start grafting shortly after the first of the year ending in February in time to start our outside work. A side veneer graft is used for most plants.

Scions are collected, labeled, and placed in plastic bags. The understock and scions are brought to the grafting area and prepped for grafting. A side veneer graft is used for most plants as it makes a better union and looks more natural as it develops. The graft is secured using rubber bands and given a quick dip in a crock pot of wax heated to 155°F. Each plant is strip tagged with scientific name, graft date, and grafter's name then place back on the bottom heat. Many scions will start to push within 2 weeks depending on the species. Once the graft has knitted rubber bands are removed. Plants are fertilized and suckers removed to keep the scion actively growing. Some standards producing a 15-18-in. head before they are moved out in late spring, many reaching a small saleable size by late summer, while most finish as nice specimens in the 2nd year. Some trees can exceed 6 ft before they are moved out.

If we have a failed graft we check the understock for active roots. Understocks generally do not stop growing and often there are windows of opportunity to re-graft failed grafts.

We want to keep the plant actively growing. When plants are taken out of the graft house they are acclimated in light shade. Plants are graded and the strongest shifted to 5-gal containers as soon as possible producing large whips or well branched plants by the end of the first season. The 2nd year they are well formed specimens ready for the field or for sale in our container program.

Root Performance … Doing More, with Less©

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Starting with a good quality substrate that promotes a good level of porosity is the first step, followed by choosing the right container design that will promote air pruning of the lateral root system. With the right container design in combination with quality substrate, air porosity will develop a strong root system providing increased uptake of water and nutrients resulting in faster growth, better caliper, improved drought tolerance, and high seedling quality. This is the key to keep good customers returning and having them pay the higher value for your seedlings. "Root performance," is the objective for managing for what you do not see, enabling you as owner, grower, manager, or propagator to produce your crops "with less" input but receive "more output".

Root system health is dependent on a good balanced level of oxygen and air porosity. The necessity of O_2 is required to deliver the needed nutrient balance to the surface of the root tissue. Too much water in your medium over a given time can create anaerobic conditions in your containers creating off-gases that are unhealthy for O_2 production and fine root system development. Uptake of nutrients is dependent on a healthy root system tissue, rooting environment, and continual production/branching of a lateral root system (unobstructed). Ideally, you want to increase your root-to-soil surface area as quickly as possible in the early stages of plant development, whether you are starting from seed, cuttings, or tissue culture (look at lateral root growth as your total catch basin, like an umbrella effect). To achieve this goal, container design and media quality are required at the start of your propagation.

It's been proven in scientific studies that short lateral roots (less weight) have a higher level of hydraulic conductivity compared to longer vertical (heavier weight) roots. To achieve roots of this nature, container design must not have a "barrier or wall" or vertically positioned obstructions which deflect roots downward (hopefully not upward) from their natural horizontal position. This is why the Jiffy pellet system is called an "Open Wall Propagation System" (Fig. 1), especially when combined with the Jiffy Air Tray System. The netting/mesh surrounding the pellet allows the medium to be compartmentalized and at the same time, allows roots to develop a natural lateral formation and prevents an artificial water table from developing (parabolic water curve — ability of solid vertical walls to create friction slowing drainage of water based on gravitational pull). The Jiffy pellet allows for natural drying to occur unobstructed.

Fig. 1. Jiffy pellet system.

Another key factor determining root performance is physical positioning of the plant at time of initial root growth. Central positioning is very important to start proper root symmetry, from the initial start of lateral root growth (Fig. 2). Root symmetry determines your net radial production area and receiving area for your water/nutrients. Plants typically will produce 5-8 main lateral roots, and you definitely want these to develop symmetrically at the top of the container having natural root form. This is the start of your main growth engine and will determine how the rest of the plants root system will develop. Root symmetry at this stage in combination with container design has a high degree of influence on root quality once the plant is planted to its final growing location (affects future plant stability and stem quality).

Fig. 2. Central positioning of plant at time of initial root growth.

Obtaining crop consistency and uniformity can be successfully accomplished through proper water and nutrient management (Fig. 3). With quality medium, consistent medium volume per cavity and uniform watering, you are on your way. With cell volume consistency, cell or tray weights can be calculated and developed accurately. Tray weights will never lie and will aid when to water/fertilize in crop scheduling. Combine this with root and soil quality, now you are ready to improve growth rate, plant quality and propagation time — “More for Less”. Tray weights allow you to manage air porosity levels in your substrate and therefore, create the best growing environment for root health (eliminates the guessing).

Fig. 3. Crop consistency and uniformity can be successfully accomplished through proper water and nutrient management.

When developing tray weights, the main weights to determine and record are:

1) Total saturation weight [100% water capacity or moisture content (MC)] — sit tray in water for 10-20 min.
2) Field saturation weight (70-80% water capacity or MC).
3) Wilting weight (depending on species the range is 35-55% MC).
4) Dry weight [oven dry weight (ODW) is not necessary, you want the minimum dry weight (DW) to where fiber damage has not occurred and fiber resiliency still exists — this is around 10% (±5%) MC].

First, you need to know the dry weight of each cell or the dry weight of a tray (Example, Jiffy pellets are delivered to customers at a DW, from here we know that pellets (depending on mix) will absorb on average 5-7 times their dry weight). Knowing the dry weight of a cell or a tray, you can calculate the remaining weights required to manage your fertilization/watering regime. Tray weights help eliminate fear from growing, tray weights will allow you to train the inexperienced and experienced propagators equally, minimizing the extremes of mortality and aiding in IPM. Healthy plant propagation becomes more in control for the propagator and owner. Knowing the weight balance provides the incentive to know when to water at a particular growth phase of the plant depending on stage of root growth within the cavity.

Table 1 provides an example of how pellet weight influences percent air content in a Jiffy 30-mm pellet, with various expanded heights. Stay in the green zone (30-15% desired air content) and out of the red zone (35% and 10-5% air content).

Table 1. Effect of expansion on percent air in 30-mm pellet.

Pellet	Dry Dia.	mm	**30**	**30**	**30**	**30**	**30**	**30**
Pellet	Exp. Ht.	mm	53	54	**55**	56	57	58
Pellet	Vol.	cc	40.7	41.4	**42.2**	43.0	43.7	44.5
			Weight in grams					
Desired Air Content (%)	35%	Dry	26.4	26.9	**27.4**	27.9	28.4	28.9
	30%	Normal	**28.5**	**29.0**	**29.5**	**30.1**	**30.6**	**31.1**
	25%	Normal	**30.5**	**31.1**	**31.6**	**32.2**	**32.8**	**33.4**
	20%	Normal	**32.5**	**33.1**	**33.7**	**34.4**	**35.0**	**35.6**
	15%	Normal	**34.6**	**35.2**	**35.9**	**36.5**	**37.2**	**37.8**
	10%	Wet	36.6	37.3	**38.0**	38.7	39.3	40.0
	5%	Wet	38.6	39.3	**40.1**	40.8	41.5	42.3

For every pass of a watering boom or every second of watering from a stationary nozzle, a certain amount of weight is added. This weight can be calculated to accurately determine how many passes or seconds are required to reach field saturation, and avoid over-watering into the complete saturation zone or low air content. More is not always better and weights help prevent this from happening, eliminating the guess work. If the tools are available, why not use them to your advantage? Yes, weighing trays takes time, but this application allows you to potentially grow more uniform quality plants per unit area (“More” growth with “Less” resources). This action results in increased sales and revenue allowing you to offset your initial labour input of weighing a few trays. By managing air content, watering/fertilizing when needed, plants will respond with a return of increased growth and possibly decreased propagation time (Fig. 4). In the right container system like the Jiffy pellets, combining all the qualities listed above, plants can be accelerated from the propagation area sooner and sold quicker to customers (In a Jiffy pellet or Preforma cell a root plug or cage is not needed to handle/extract the plant from the tray).

Fig. 4. By managing air content, watering/fertilizing when needed, plants will respond with a return of increased growth.

Stress: the Silent Killer©

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INTRODUCTION

Plant stress is a problem that can have immediate or longer-term consequences. While individual stressors, such as hail damage, can be identified as a single cause of plant problems it's more common to have more than one stressor involved. Multiple stressors can result in damage either concurrently or sequentially.

My definition "stress" is the condition where an environmental factor or factors exceed the natural regulatory capacity of a plant and results in decreased growth or performance. Why do growers become frustrated when told that the problem is due to stress? To maximize returns, nurserymen need to control as many production variables as possible and stress is typically unpredictable and not always manageable.

Plants are adapted to their native habitat so a key factor in diagnosing stress-related injury is to understand environmental factors that make up the habitat in which they perform best. Important environmental factors include temperature, moisture (including humidity), light quantity and quality, wind or the lack thereof, soil characteristics, and nutritional needs. Each part of the plant's native environment when compared to a new environment helps identify how well a plant adapts.

While it may be stressful, without being able to grow plants outside their native habitats the nursery industry wouldn't exist. Changes, and especially extreme changes, can result in plant damage. Because of limited environmental niche options and the desire to maximize growth while seeking to control growth characteristics, perhaps one of the most stressful locations for a plant to grow is in the nursery. Some plants, however, are more adaptable than others.

It's important to identify locations in the nursery where plants can maximize growth while developing structural characteristics (straight leaders, appropriate branching, good foliage density, etc.) needed for sales. While there are exceptions to rules, deciduous plants tend to adapt better to exposed sites than evergreens. Broadleaved evergreens generally do better in partial shade than full shade (because they can get leggy) or in full sun (because they can burn). Evergreens that have a heavy leaf cuticle, however, will perform fairly well under warmer conditions and low growing broadleaved evergreens may actually make up a better plant in full sun than in the shade. Root systems are also a factor with shallow and fine-rooted plants generally not performing as well in light soils as coarser-rooted plants. Plant hybrids take on characteristics from each parent and will result in environment adaptability differences. Of course, there are exceptions to every rule.

Nurserymen can generally see a plant going off-color and recognize the gradual decline of an optimally performing plant to a poorly performing plant. The best chance of optimizing growth occurs when one can identify the earliest stages of decline and initiate a remedy quickly. One needs to remember that damage from environmental stressors can cause a range of symptoms on different types of plants so it's critical to be able to see the decline. Ultimately there may be a threshold point when a plant moves from poorly performing to a non-recoverable (dead) status. Recognize that it's much easier to identify poorly performing plants in a crop of good plants than when a group of plants is generally or gradually declining.

EXAMPLE 1: CATCH THE PROBLEM EARLY

Samples of rooted periwinkle cuttings were brought to the office because they weren't growing. They had been transplanted into cells in the late fall but the crop had made little progress in over 2 months. An examination of the roots showed they had not grown. I tested the pH of the medium and it resulted in a reading of 4.3. I recommended application of pelletized dolomitic lime. Figure 1 was taken about 3 weeks after treatment and roots had already started to grow but foliage was still weak.

Fig. 1. Periwinkle (*Vinca*) 3 weeks after pelletized dolomitic lime application.

Fig. 2. Plant growth by early April after pelletized lime application.

My diagnosis was that the *Vinca* had a pH threshold effect that caused cessation of root growth. Because of the fine mesh size of pelletized lime (finer than pulverized lime), it worked quickly and by early April (Fig. 2) the pH was 5.1. By that date, 50% of the crop had been sold, 40% were coming on strong and 10% were un-saleable. The bottom line is to catch the problem early while there is a chance for recovery.

Growers need to anticipate stressors that may arise. Container growers prepare for cold winter temperatures by constructing and covering structures used in container production with white (milky) polyethylene. When covered, low temperatures inside the structure are increased and high temperatures are reduced. Inside air movement is also reduced while humidity is increased and medium moisture (the most important protection against root cold damage) is maintained. The ability to add summer shade to these structures can also reduce summer stress or impacts.

For field production, hedgerows reduce the impact of wind, provide some shade, somewhat increase humidity and help maintain soil moisture. Locating plants sensitive to late-spring and early fall frost higher on slopes helps reduce frost problems. Plants sensitive to excess moisture may also perform better higher on slopes because soils tend to be lighter as finer textured particles are moved down the slope and accumulate in the lower areas due to erosion.

When natural stressors can be anticipated, they can be managed. Sometimes however, stressors, and especially combinations of stressors, such as hail, excessive snowfall, ice, excessively high wind events and very low humidity cannot be avoided or even managed.

EXAMPLE 2: TIMING IS EVERYTHING

A grower had an older Quonset-style propagation house that, following a major snowstorm, was piled high with snow. The snow was followed with freezing rain that created heavy wet load on the structure and that resulted in his son's concern about the potential for snow-load damage. The father didn't think it would be an issue but allowed his son to place supports in the structure, reducing the son's concerns. After the snow melted off the structure the supports were short of the ridge by about six-inches. His son, in all probability, saved the structure and the crop.

Timing is everything in nursery operations. Whether irrigating early enough to avoid having wet foliage going into the night to reduce foliar diseases, controlling weeds before they have time to establish and set seed, identifying insect issues before populations get out of control, or selling plants at the time of flowering; all result in reducing operational inputs or maximized returns.

Timing, as related to the stage of growth of a plant, may be the most important factor involved in stress-related damage. Over the years I have seen many instances of the same type of plants growing in essentially the same location where one has damage symptoms and the one next to it does not. For most of these issues, the plant's stage of growth at the time of stress was the only variable option that I could attribute to the problem.

I was called to evaluate damage on young fir trees where new growth had foliar burn. The most severe damage was on the south side of the plant while the eastern and western exposures had partial damage and the north side had none. The cause of the problem was a combination of the plant being in a susceptible stage of growth (the plant had de-hardened and buds had begun to swell) and the exposure to high levels of sunlight. In the early spring, the combination of new growth and heat buildup caused by the angle of incidence of sunlight being more directly focused on the side of the plant will result in this type of damage.

Stage of growth issues not only relate to environmental damage but also to chemical damage. The application of chemical sprays when growth is succulent has a much higher probability of damage than application on mature foliar growth.

The *Hydrangea paniculata* plants pictured below (Fig. 4) had what appeared to be a chemical burn. Plants that were near or at flowering did not exhibit damage while almost all the plants in a vegetative growth stage were damaged. The only variable was related to an application of a pyrethroid that occurred during a susceptible stage of growth.

Fig. 3. Young fir trees where new growth had foliar burn.

Fig. 4. Stage of growth issues relate to chemical damage on *Hydrangea paniculata*.

EXAMPLE 3: A COMBINATION OF STRESSORS ON PLANT GROWTH

Combinations of stressors will typically result in much more damage than individual stressors and those combinations can occur concurrently or sequentially. As a baseline, think about a hemlock (*Tsuga canadensis*) under high sunlight conditions as a single stressor. Add in high temperature that causes additional stress on this understory plant. Combine those with low soil moisture, reducing the ability of the plant to transport enough moisture to the leaves. Next, include low humidity into the equation that creates even more demand for water and follow that with high winds. This scenario creates almost the "perfect storm" for creating stress-related plant damage. The photo of hemlock leaves depicts the resulting damage (Fig. 5).

Plants under stress are more likely to have secondary problems. Those problems can include disease infection, infestation by insects, and increased susceptibility to other environmental plant stressors.

Fig. 5. Illustrates the results of a combination of stressors on hemlock.

We have monitored for exotic bark beetles using traps with various lures as attractants. Lures included ethanol and α-pinene along with some more sophisticated pheromones. Why ethanol and α-pinene? As trees are stressed, one of the biochemical products generated is ethanol while the strong pine tree smell is α-pinene. The strong pine smell of α-pinene is the same smell one senses when sap exudes from trees under stress from cankers, insects, broken branches, or even pruning cuts that weep pitch. Both the ethanol and α-pinene attract insects that will do further damage to trees.

EXAMPLE 4. DIAGNOSING PLANT PROBLEMS REQUIRES EACH OF US TO BECOME DETECTIVES

There are clues that need to be identified and correlated so a solution can be found. There are often times when interviews with those who work closest with the crop will generate very useful information. Tests previously conducted may also help in finding a solution. The key, however, is to proceed in a logical progression toward the solution. Be sure your procedures will not taint the outcome. Review the methods by which information developed by others is determined. Sometimes it's better to start with a clean slate

Top growers in our area consistently look for ways to reduce environmental impact. During one incident, electronic water sensors were used to monitor moisture levels and schedule irrigation cycles. Plants declined during an extended period of high heat with a few short showers. Symptoms were consistent with a soluble salt problem. Media samples taken from the containers were checked for electrical conductivity by a commercial lab and the results were normal.

I performed a sequential pour-through test to identify soluble salt fractions throughout the container. I slowly added water to the medium from the top to avoid channeling (when clear water runs through unabated) and started capturing water as it ran out the bottom, partially filling one beaker or glass after another. Capturing more fractions (samples) works better than fewer. I then tested each fraction for soluble salt content.

The results told a different story from earlier analyses. Low electrical conductivity levels were found at the top and bottom of the container but levels peaked in the middle of the container (Fig. 6).

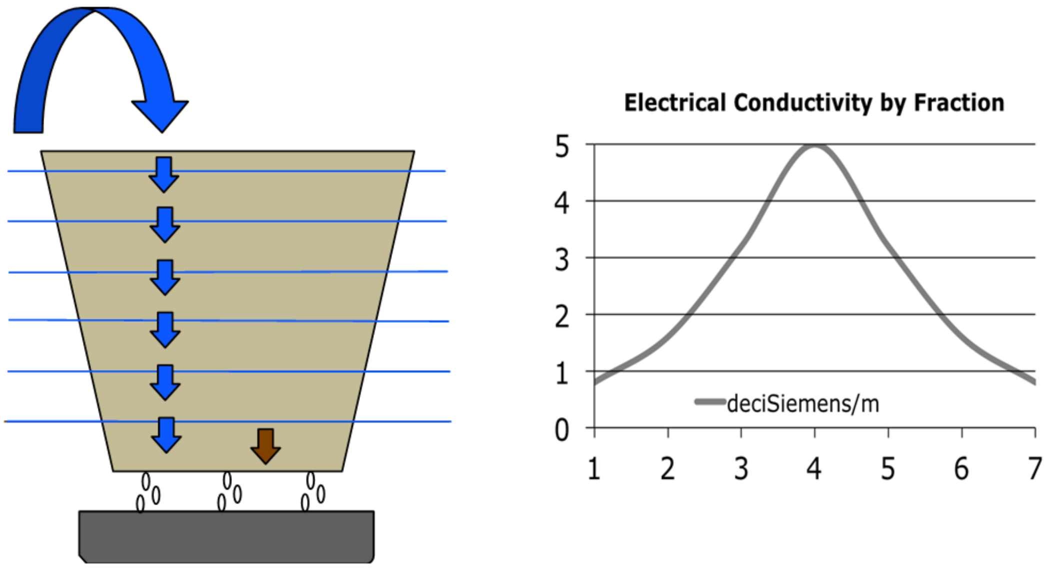

Fig. 6. Sequential pour through (left) and electrical conductivity by fraction (right).

In all probability, limited rain and irrigation had pushed salts deeper into the medium but there wasn't adequate liquid to leach soluble salts out. The lack of salts at the bottom was probably caused by capillary action from the water moving across the floor covering. Peak soluble salt levels were easily high enough to damage plant roots and those were found in the middle of the container where roots were concentrated. Plants less damaged were located near the outside of the house and that was attributed to additional irrigation water from an adjacent house. My recommendation was to include regular leaching cycles during irrigation.

The best way to start toward diagnosing plant problems is to keep a journal of historical plant problems and diagnoses. The journal should include when problems occurred, where problems occurred, weather conditions at the time of the problem, and weather conditions during the period leading up to the problem. Weather information needs to include temperatures, temperature extremes, light conditions, humidity, the amount of rainfall, and wind conditions. Note any stresses the plant may have sustained: soil moisture levels that include water deficiencies or excesses, fertility issues, chemical applications and mechanical damage. Note if the damage appeared suddenly or was progressive and if on random or grouped plants. Always check for biotic (living) organisms such as insects, mites and diseases and try to determine if they are primary or secondary problems.

Symptoms of the same type damage can vary from plant to plant and especially between various types of plants. Don't assume all plants in a location are exhibiting damage from the same stressor. I refer back to the fir tree that had damage due to the southern exposure. The series of three photos below (Fig. 7) were taken on the same day in the same field with various symptoms. From left to right, they were diagnosed as foliar scorch on the southern exposure, *Phytophthora* root rot, and frost damage that occurred when new spring growth was exposed to freezing temperatures.

Fig. 7. Same field but three different symptoms and three different causes.

Fig. 8. Different causes but same symptoms.

The photo above (Fig. 8) shows two Canaan fir trees with similar symptoms at the base, a clear browning of the leaves. A stem canker caused damage to the tree on the right while damage to the one on the left was caused by mechanical damage.

To verify a diagnosis, determine if a nearby plant of the same type has the same or similar symptoms and check for other nearby plants that might have similar or related symptoms, even if they are not of the same type. Have another set of eyes evaluate those situations in question. There are always others with more information on a specific type of plant. Finally, especially when an answer is not readily forthcoming, sleep on it. It's amazing what comes to mind while relaxing and not focusing on the problem.

SUMMARY

In closing there are a few points to remember:

- If journals are not kept that include detailed notes of incidents, solutions will be lost.
- It's important to understand why a problem occurred. (If an answer can't be found it will probably come back to haunt you.)
- Experience is the best teacher and experience of others is far more cost effective than personally experiencing it.

Rose Rosette Disease and the Impacts on Propagation©

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In order to have our businesses be successful forces in the plant industry, we need to be attentive to our environment and potential pests that might destroy our crops and landscapes. Throughout history we have witnessed many pests that have forever changed our thinking and our practices in horticulture. Pests like Japanese beetle, gypsy moths, emerald ash borer, Dutch elm disease, chestnut blight, sudden oak death, downy mildew of impatiens, and many others have spread rapidly causing plant lovers to reevaluate their plant palettes and practices. I am deeply concerned about a disease that is spreading quickly and that has the potential to change the way we grow and look at the beloved genus of *Rosa*.

Throughout history roses have been admired for their beauty, perfume, food, drink and medicinal properties. The rose has been admired through art in paintings, in china, architectural elements, and illustrations. Everyone seems to appreciate the beauty of the rose. At least 10 countries have selected the rose as their national flower including the United States of America. What would our landscapes be without roses adorning them?

There is a rapidly spreading disease that threatens the genus *Rosa* throughout the Midwest and has also been identified west of the Rockies. The disease of concern has been identified as rose rosette disease (RRD) also termed rose rosette virus (RRV).

Rose rosette disease was first detected and identified in the early 1940s in Manitoba, Wyoming, Nebraska, and California. It is widely believed that it is a disease that is indigenous of the eastern Rockies occurring on the native Woods rose, *R. woodsii*. In the last 60 years it has spread relatively quickly eastward and is now in Iowa, Wisconsin, Illinois, Southern Michigan, New Jersey, New York, and south to South Carolina, Georgia, Alabama, Mississippi, and Texas. Reports of RRD also include Southern Ontario and New Mexico.

The interesting information about the means and reason for its quick spread is attributed to the invasive rose, *R. multiflora*. *Rosa multiflora* is very susceptible to the disease. *Rosa multiflora* was originally brought to the United States of America as a rootstock for grafting. Conservation groups from the 1940s to the 1960s thought that it could be used as a living fence to keep in livestock. It was thought to be a great conservation plant. Because of the wide spread of *R. multiflora* the virus now has a susceptible host throughout North America. In fact RRD was once considered a method of controlling this aggressive plant.

Multiflora rose is extremely susceptible to RRD but it isn't the only rose that has shown symptoms. Climbers, hybrid teas, floribundas, miniatures, shrub roses, and antique roses have all shown symptoms. There is however resistance within the genus. *Rosa setigera* and *R. palustris* seem to be completely immune.

For almost 50 years after the first sighting of RRV there was little interest in the causal agent. In 1988 the connection between the eriophyid mite (*Phyllocoptes fructiphilus*) and roses that showed symptoms of RRD was first noted. It was concluded that the wingless mite was indeed the vector for the infection. In 2011 it was confirmed that the causal agent was truly a virus (Laney et al., 2011).

The RRD virus is transmitted from infected plants to healthy plants by the wingless eriophyid mite, *P. fructiphilus*. The wingless mite is carried by air currents from infected plants to healthy plants. By feeding on the healthy plants, the mite will introduce the virus. It is believed the virus can be transmitted by the mite for up to 10 days.

Humans are another means of transmitting the virus. *Rosa multiflora* has been utilized as a rootstock for decades. If a rose is grafted onto an infected rootstock the results can be an infected plant.

It has been suspected that infected pruning shears can cause the transmission of virus.

This has not been proven but it is a good idea to keep your pruning shears disinfected between plants.

Early detection of RRD is important to help keep nearby plants healthy. Many of the symptoms can mimic damage caused by herbicides. Symptoms can also vary depending on the cultivar or species of the rose.

Common symptoms include:

- New growth has many branches (witch's broom)
- Shoots and leaves are abnormally red
- Rapid growth and elongation of shoots
- Shortening of internodes
- Distorted leaves
- Deformed buds and flowers
- Overabundance of thorns that are pliable
- Lack of winter hardiness

Fig. 1. Leaf symptoms from rose rosette disease (image supplied by Norm Scherr 1629 Briar Ridge, Ann Arbor, Michigan 48108).

The Department of Entomology and Plant Pathology at Oklahoma State University are at the cutting edge of diagnosing the RRD virus (Olsen, 2013). The test they are doing isn't 100% accurate but they are getting good results.

There is no cure for RRD. Plants that show symptoms should be destroyed as a means of sanitation. All parts of the plant including roots need to be disposed of in a timely matter. Any *R. multiflora* in within 100 yards of your roses should be eliminated if possible. Using miticides can be effective to eliminate the eriophyid mite vector. The scouting and elimination of infected plants is the most judicious solution.

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