complex of pests.

With several pests being present at any one time, the control of the other pests present will necessitate the use of chemicals. For example, effective control of mites with predators and without pesticides may allow other pests, such as aphids and worms, to develop to the point where chemicals are needed to control them. These chemicals, in turn, will destroy the beneficial mite predators unless careful attention is given to their selection and proper timing of application. In general, it is more difficult to develop a successful biocontrol program on a crop such as ornamentals with such a diverse complex of pests.

The predators and parasites will not control 100% of the pest population as there must be a small population of pest present to maintain these beneficials.

Utilization of parasites and predators for control of pests is slow when compared to pesticides. Materials such as *Bacillus thuringiensis* do not kill quickly and there will be a great amount of damage before the materials start to take effect.

To establish a good biological control program, a qualified person knowledgable in the priniciples of biological control must be contracted to initiate the program. If a grower commits himself to the principle and starts on the project, he must follow through with the entire program. He should expect that it may take some time before any results are observed.

IPM is an all-inclusive approach to pest control and at the present time I do not believe that with the resources we have the industry can accept the concept wholly. However, there are many features in the concept the grower can take and put to good use.

PROPAGATION OF GIANT SEQUOIA BY ROOTING CUTTINGS

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Several years ago, in a paper on the advantages of reforestation with vegetatively propagated trees, Bill Libby wrote: "The genetic leverage available with vegetative propagation makes reforestation using rooted cuttings . . . (an) attractive new management technique . . .". Since that time, the use of vegetative propagation in forestry has increased, and several countries, including

Canada, Finland, and West Germany currently have large scale operations for rooting cuttings for reforestation. It is my contention that the same option is open to us with some of our local species, including the one I will discuss today — the giant sequoia (*Sequoiadendron giganteum* (Lindl.) Buch.)

Many people are familiar with this spectacular California endemic. It is grown widely in Europe and this country as an ornamental. The species is native in modern times only to the west slope of the Sierras, but we know that in earlier geologic periods its ancestors grew in Europe, Greenland, and Spitzbergen. Changing climates over geologic time appear to be associated with its migration and current restriction in range (1,2,4).

Several years ago, Rundel (6) found that moisture gradients dropped sharply beyond the boundaries of the Giant Forest population of giant sequoia. This finding may be a clue to the species' limited range, and one might speculate that it is limited summer moisture that discourages the establishment of new seedlings outside the geographic boundaries of extant populations. However, the success of many ornamental plantings, and many small forest plantings, leads one to believe that, once the problem of establishment is overcome, giant sequoias can survive and grow well in a wide range of climates and soils.

The rapid growth and substantial size of ornamental plantings of giant sequoia, while impressive, cannot be taken as representative of the real average growth potential that can be expected in a forest environment. However, measurements taken in 41 forest plantings in California and Oregon show that giant sequoia often performs as well as other competitor species and, in several plantations, surpasses the competitor species in height and/or diameter at breast height (3).

In addition, work at the University of California at Berkeley shows that juvenile giant sequoia is easily cloned via rooting cuttings (3,7), making giant sequoia an attractive experimental organism for genetic studies as well as a likely candidate for clonal forestry.

In this paper I will discuss three cloning experiments — a fertilizer experiment, an experiment with cutting technique, and a very small, but interesting, experiment with older giant sequoia material. The purpose of these experiments was to develop techniques that would promote giant sequoia cuttings to root with consistency and reliability.

MATERIALS AND METHODS

By 1975, Libby had developed a "standard rooting procedure" for radiata (Monterey) pine as follows: branch cuttings were trimmed (usually to 6 to 8 cm) and soaked in a Benlate (benomyl) solution at 1.13 gm/gal of water for ½ hour. After removal from Benlate, a fresh basal cut was made, and the cuttings were dipped in a solution of indolebutyric acid (IBA) at 4000 ppm in 95% ethyl alcohol. The cuttings were then stuck in preformed depressions in the medium and placed on a mist bench where they received two morning mist sprays and three afternoon sprays, each of approximately 1-minute duration with 1 hour between them. Daylength was extended by incandescent lights to 16 hours; bench temperature was not controlled. Summer temperatures were modified somewhat by whitewashing the greenhouse in March or April, depending on the weather. The standard rooting medium consisted of equal parts of Canadian sphagnum peat, nitrogen-charged redwood sawdust, and oak leaf mold.

Fertilizer Experiment: In this experiment, 380 cuttings were set from 232 six-month-old seedings from many different populations. All of these seedlings were greenhouse-grown in Albany, California. Cuttings were stuck in Leach supercells (one cutting per cell), and systematically assigned to one of three treatment groups as follows: 147 received no fertilizer, 141 received Ortho Azalea Food (10N-8P-7K) at 1 tbs/gal, and 92 cuttings received Ortho Upstart (3N-10P-3K) at 4 oz/gal. Cuttings were fertilized weekly with sufficient fertilizer at each application on reach the lower end of the cuttings (2 to 3 cm into the rooting medium). The cuttings were sprayed with water after each fertilizer application to prevent damage to the foliage. Cuttings were considered rooted when the first root extended to the bottom of the container.

Results: Rooting results after 6 months are shown in Table 1. Controls rooted at 70%; Azalea-food treated cuttings rooted at 88%, and Upstart-treated cuttings rooted at 86%. Chi-square tests indicated highly significant differences among all treatments (P=.0002), but no significant difference between the Azalea and Upstart fertilizer treatments. Average numbers of primary roots initiated per rooted cutting are shown by treatment group in Table 2. The control group averaged 2.4; Azalea food-treated, 2.8; and the Upstart-treated, 3.6 roots per rooted cutting. Differences between treatment groups was significant (P=.006) (see ANOVA 1).

Table 1: Fertilizer Experiment. Rooting Percentage at 6 Months

Treatment	Rooting Proportion	Rooting Percentage
Control	103/147	70
Azalea Food	124/141	88
Upstart Fertilizer	79/92	86

Table 2: Fertilizer Experiment Average Number of Roots per Rooted Cutting after 6 Months

Treatment	Number of Roots Per Rooted Cutting
Control	2 4
Azalea Food	2 8
Upstart Fertilizer	3 6

ANOVA 1: Fertilizer Experiment Average Number of Roots per Rooted Cutting

Source	df	MS	F	P
Fertilizer	2	18 464	5 279	006
Residual	303	3 498		

Discussion: The results of this experiment are consistent with our other experiments carried out in the same environment Later experiments, however, in which the amount of water applied was substantially less than in the above-described experiment, do not support these findings, and suggest that under low-mist conditions, fertilizer treatments at these levels are detrimental (3).

Cutting Angle: In the summer of 1976, at the Asilomar meeting of the Western Region Plant Propagators' Society, I learned that the angle of the basal cut may influence the shape of the resulting root system. In September, 1976, I set up an experiment to test the influence of cutting angle with giant sequoia cuttings I used 203 cuttings from 36 clones from 14 population samples. Approximately half of the cuttings were cut at a 45° angle, while the others were cut at a 90° angle Cuttings were set in clear plastic containers (Pickering tubes). The medium in the lower ⅔ of the container consisted of equal parts of Canadian sphagnum peat, #2 sand, and redwood soil conditioner, plus 4.5 lb dolomite lime, 2.5 lb superphosphate, ¼ lb ammonium nitrate, and ¼ lb potassium nitrate per cubic yard of mix[1]. Cuttings were fertilized weekly with Upstart at 4 oz/gal of water.

Results: After 2 months, the angle-bottomed cuttings had rooted 47%, and the straight-cut ones had rooted 28%. After 3 months they had rooted at 84% and 76% respectively and, after 9 months, rooting percentages were 90 and 83, respectively, with both groups averaging 4.3 roots per rooted cutting.

Discussion: I did not find differences between treatments in the number of roots per rooted cutting. But, it appears that angled cutting may be associated with greater speed of rooting, and possibly higher rooting percentages This experiment was not replicated, and should be repeated. Angled cuts have now become part of the standard rooting procedure for giant sequoia.

[1] This mix was developed at the University of California at Davis

Rooting Older Cuttings: In October, 1975, I attempted to use the standard rooting technique on cuttings from several 40-year-old giant sequoias growing on Kimberley-Clark land in northern California. After 11 months on the mist bench, not a single cutting had rooted, but some appeared to be still alive, and had healthy white callus tissue at the base. I saved 30 of the best ones, dipped 15 of them in IBA at 4000 ppm for 5 seconds, and kept the other 15 as controls. All of the cuttings were reset on the mist bench. Callus tissue was not intentially damaged in the process, although both sets of cuttings were disturbed when they were removed from the medium

Results: After 10 additional weeks on the mist bench, 13 of the 15 IBA-treated cuttings had rooted, and only 2 of the control cuttings had rooted. All 15 rooted cuttings were transplanted and moved to a University of California greenhouse in Albany, where they were fertilized weekly with Azalea food at 1 tbs/gal of water. During transplanting, it was noted that the root systems were generally small and delicate, the tops dry and off-color. By May, only 2 of the plants were still alive.

Discussion: It appears that the second IBA treatment was associated with rooting in these older cuttings. The clear difference in rooting between the two groups indicates a real effect (87% compared with 13%), but the experiment was very small, and should be repeated on a larger scale.

Why most of the cuttings died after rooting and transplanting, remains a mystery; this is not the usual case with juvenile material. If the problem can be solved, it would open the way to propagate unusual mature adults for ornamental plantings, and would also make possible the use of mature individuals for seed orchards. This aspect of propagating giant sequoia is yet a challenge.

SUMMARY

The experiments presented here show that juvenile giant sequoia material can be clonally propagated with some ease by rooting cuttings. Rooting percentages under favorable conditions have been in the high 80's and 90's, and, in one experiment, rooting began after only 10 weeks on the mist bench. Mature material can be rooted with some difficulty. However, problems have been encountered in keeping this material alive after rooting has taken place.

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DELETERIOUS METABOLIC AND MORPHOLOGICAL CHANGES RESULTING FROM SEED SOAKING PRIOR TO SOWING

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For many years growers have soaked seeds prior to sowing in the belief that germination will often be improved. However in many cases exactly the opposite effect is achieved; that is, germination will be reduced or seedling growth will be abnormal. A further reason to study soaking injury is highlighted by new changes in cultural practices. Recent work has focussed more attention on seed soaking prior to sowing as a means of improving field or greenhouse seedling emergence and uniformity. Two striking examples highlight this:

1. The use of pre-germination chambers to prepare materials for fluid drilling. This interesting technique is now used by growers of high value vegetable crops in many countries and is the result of recent research work at The National Vegetable Research Station in England (12). The method is also suitable for small scale use (7). It seems highly likely that this technique will prove useful for woody ornamental plants as well as other ornamentals. Indeed, equipment is now being developed for the bedding plant industry for this purpose.
2. The use of osmotic priming techniques for seeds. Using this method seeds are partially hydrated in a controlled manner.