Bougainvillea Propagation

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INTRODUCTION

Bougainvilleas are spectacular climbing plants, native to South America. In Australia, although they certainly grow best in warmer areas, they can be found growing outdoors as far south as Hobart (Latitude 42 S), if given the right position.

This paper is not meant to cover all aspects of *Bougainvillea* propagation; rather, it describes the methods used at our nursery.

CUTTING PROPAGATION

Stock Plants. We grow the majority of our stock plants in containers because of the control it affords us over production. We have also found that some types, particularly of *B. glabra*, are more productive as young (1- to 2-year old) plants and this allows us to obtain our cutting material from potted stock and then sell the plant. Stock plants are grown under cover (plastic film) to regulate watering and reduce foliar disease. Nutrition is supplied by the application of controlled-release fertilizer (Osmocote) annually, which is supplemented by an application of nitrogen (I.B.D.U. at 1 g/liter) after each cut. Trace elements are supplied as required.

When cutting material is removed from the stock plant, the plant is pruned back to a leaf less stump from which we encourage the production of 6 to 10 canes.

Stock plants grown in 300-mm diameter pots give us about 150 cuttings per year from four harvests, whereas our outdoor stock gives us up to 1000 cuttings per year from two harvests. Material produced from potted stock plants gives us more uniformity in quality than that produced from in-ground stock.

Cutting Preparation. Cane is collected two or three times daily and kept moist by spraying with heavily chlorinated (200 ppm chlorine) water. Cuttings are harvested from September until May and range from hardwood through firm tips—our preference being for wood which is changing from green to brown in colour. The length of the cutting depends on the type of plant we wish to produce. The vast majority of cuttings are prepared as 4- to 6-node cuttings, 100 to 125 mm long with 3- to 6-mm caliper. Other cuttings are prepared up to 1.8 m long to produce "standards" or "lollipops". These have calipers up to 30 mm. With our smaller cuttings, the top two leaves are retained and these have their leaf area reduced by at least 50%. The large cuttings are prepared leafless.

Cuttings are treated with hormone powder and then set out in 50-mm plastic tubes containing a mix of 10 parts perlite to 3 parts peat moss. We use IBA at strengths varying from 4,000 to 16,000 ppm, depending on cultivar and the time of year.

The Propagation Shed. Trays of cuttings are placed in a plastic-covered igloo. Bottom heat is used to maintain a bed surface temperature of 25 to 27°C and intermittent mist is applied to maintain humidity. As bougainvilleas do not tolerate a wet environment, the application of mist needs to be carefully monitored.

Cuttings receive a light application (150 ppm N) of foliar feed 2 to 3 times each week until root formation is evident (generally at 3 to 4 weeks). Rooted cuttings are removed from the propagation shed, controlled-release fertilizer is applied and plants are held under either light shade or plastic film. During periods of wet weather a copper spray is applied weekly to reduce the incidence of bacterial leaf spot, the only significant disease of *Bougainvillea* in Brisbane.

OTHER PROPAGATION METHODS

Bougainvillea does not readily set seed in Brisbane. Our limited experience with seed has shown that fresh seed germinates readily in about 3 weeks, but we have yet to produce a useful plant from seed.

There are several references in the literature to budding and grafting of *Bougainvillea*, but we have not used these techniques ourselves. Similarly, *Bougainvillea* have been successfully tissue cultured, however, I doubt that this would be economic, given the length of time required to produce a saleable plant and the high success rate of conventional cutting propagation.

Stimulation of Seed Production in *Eucalyptus* by Paclobutrazol Application

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INTRODUCTION

In Tasmania more than six million eucalypts are established in plantations each year. The seed requirement for such a planting is quite large. Many eucalypts tend to be biennial in flowering but often flowering at much longer intervals. This causes seed production to be erratic and supply nonuniform.

The growth regulator paclobutrazol has been shown to enhance flowering and seed set in *Eucalyptus* (Hetherington et al., 1991). Application of paclobutrazol in late February to March can promote flower bud production (a reproductive effect) within the first year of application; whereas November application does not produce a reproductive effect until the second year after application. The aim of the current work was to examine timing effects and to broaden our knowledge of the reproductive effects of paclobutrazol application.

METHOD

Trunk Application. Holes were drilled 5 cm deep every 15 cm around the tree. Clipper, 2% active ingredient (ai) paclobutrazol, was applied through a tube placed in each hole. This enables passive uptake by the xylem. Application rates varied from 0.017-0.067 g ai/cm circumference (circ.) (Table 1).

Collar Drench. Weeds were removed from an area (0.5 m radius) around the base of the tree. Solutions of Cultar (25% ai) were poured over the base of the trunk and the cleared area adjacent to the tree. Application rates varied between 0.25-1.0 g ai/cm circ. (Table 1).

Current Trials. Six experiments were initiated between August 1990 and May 1991. None of the trees had produced flower buds, to any significant degree, prior to treatment. Experiments were conducted at 3 sites in northern Tasmania.

Tree height and circumference were measured to assess tree size. Visual assessment of all trials was carried out during February to April 1992. The intensity of flower buds on each tree was recorded as a visual score: 1 = no buds, 5 = heavy crop. A mean bud score was calculated by averaging individual tree scores. Statistical significance was tested by using a t test for each treated vs control comparison.

RESULTS

Reproductive effects of paclobutrazol, applied as Clipper or Cultar, over a number of experiments are shown in Table 1. Stimulation of flower bud production was most apparent in experiments 3, 4, and 6. Precocious bud production was not evident in experiments 1 and 2. The intensity of flower buds on treated trees in

Table 1. Flower bud production on six experiments using paclobutrazol on *Eucalyptus nitens* and *E. globulus*.

Exp. No.	Species	Treatment: Age at	Treatment: Date	Treatment: Mode	Paclobutrazol rate (g ai/cm circ)	Trees with flower buds (%): Treated	Trees with flower buds (%): Control	Mean bud score [1,2]: Treated	Mean bud score [1,2]: Control
1a	*globulus*	3	13/8/90	Cultar drench	0.3	30	5	1.5 [a]	1.1 [a]
1b	*globulus*	2	13/8/90	Cultar drench	0.9	25	0	1.3 [a]	1.0 [a]
2	*nitens*	3	2/10/90	Cultar drench	0.3	70	40	2.3 [a]	1.4 [a]
3	*nitens*	4	10/5/91	Trunk application	0.03	100	71	3.6 [a]	1.4 [a]
4	*globulus*	4	10/5/91	Trunk application	0.03	75	15	3.1 [a]	1.3 [a]
5a	*nitens*	7	24/5/91	Trunk application	0.017-0.067	83	50	2.7 [a]	2.0 [a]
5b	*nitens*	7	30/5/91	Cultar drench	0.25-1.0	58	50	1.9 [a]	2.0 [a]
6	*nitens*	10	25/5/91	Trunk application	0.017-0.067	100	50	3.8 [a]	1.5 [a]

[1] Trees assessed Feb.-March 1992. 1=no buds, 2=poor crop, 3=average crop, 4=good crop,5=heavy crop.

[2] Within each horizontal line, means followed by different letters are significantly different at 5% level.

experiment 5 was not greatly different to that of the controls, however, no significant reduction in vegetative growth was observed in this experiment. Tree growth, measured as trunk girth, was reduced more by paclobutrazol than was height growth (data not presented). The results of experiment 5 suggest that Clipper is superior to Cultar for stimulating flower bud production.

Paclobutrazol applied in spring 1990 (experiments 1 and 2) did not produce a reproductive effect until more than one year after application. Autumn application generally produced a reproductive response within one year of application (experiments 3, 4 and 6).

DISCUSSION

One explanation for the observed effects of paclobutrazol is that it reduces vegetative growth, thereby diverting more assimilates to reproductive growth (Shearing et al., 1986). Jones et al. (1988, 1989) have found a negative correlation between vegetative growth and flowering in apples. Buds of *E. nitens* are initiated in late spring to early autumn (November-March), whereas in *E. globulus* buds are initiated in spring and summer. Paclobutrazol applied to *E. nitens* in October or *E. globulus* in August did not induce bud initiation in the forthcoming season (experiments 2 and 3); whereas application in March to *E. globulus* (experiment 4) and *E. nitens* (experiment 6) induced bud initiation in the forthcoming spring-summer.

Our results suggest that paclobutrazol does not have an immediate effect on flower bud production but needs to reduce vegetative growth to some degree, prior to the normal bud initiation time, before a reproductive result can occur. Perhaps the reason for the lack of significant response (in terms of flower bud intensity) in experiment 5 was that vegetative growth was not greatly reduced. This may have occurred for two reasons. Firstly, application in May could have been too late and the trees may already have entered a winter dormancy. Secondly, the trees may have been suffering from water stress. It is suggested that the reason for bud stimulation in experiment 6, which was treated at the same time as experiment 5, was that these trees were actively growing at the ti ne of treatment.

With the dosage rates used in experiment 5, trunk application stimulated more trees to produce flower buds than collar drenching. This agrees with previous work (Hetherington, unpublished data). Cultar may become absorbed by soil particles when soil moisture is low, whereas Clipper is immediately available to the tree.

Precocious flower bud production was not observed in experiments 1 and 2. A reason for this could be that trees in these trials had predominantly juvenile form at treatment and may not have been physiologically capable of flowering.

This study has focused on *E. nitens* and *E. globulus,* however, Clipper application to 4-year-old *E. grandis, E. perriniana, E. johnstonii,* and *E. nitida* (under the same conditions as experiment 4) has stimulated flower bud production (Hetherington, unpublished data). There is evidence that paclobutrazol can induce precociousness in *E. gunnii* hybrids (Cauvin, 1991) and *E. globulus* (Hasan, et. al., 1992). Paclobutrazol treatment can also enhance flowering in other ornamental trees such as *Jacaranda* and lillypilly (Pettenon, pers. comm).

CONCLUSION

Early autumn is the best time to apply paclobutrazol in order to obtain a reproductive response in *E. nitens* and *E. globulus.* Our results suggest that only actively growing trees should be treated.

Possible effects of paclobutrazol on precocious bearing need to be investigated in order to maximize genetic progress in eucalypt breeding. Further work on optimum dose rates and the differences between Clipper and Cultar application should be undertaken in order that paclobutrazol can be used effectively in seed orchard management.

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The Effects of Shoot Age on Root Formation of Cuttings of *Eucalyptus grandis* W. Hill ex Maiden

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Root formation on cuttings of *Eucalyptus grandis* is influenced by the age of the shoots on the donor plants. Cuttings taken from 8-week-old shoots rooted more frequently and with a larger number of roots per cutting than did cuttings from 16 week old shoots. The difference in rooting patterns is primarily attributed to rapid leaf senescence on the older shoots as shoots which lost more than 75% of the original leaves failed to root. Propagators should avoid using older shoots with leaves that will not remain functional during the first 2 weeks of root initiation. Roots were visible on the younger shoots within 2 weeks of their being set and the number of primary roots had reached a maximum within 4 weeks. Percentage rooting reached a maximum by the 8th week after setting. This time sequence has implications for management of cuttings production in nurseries. It indicates that there is an optimal time to change from a root initiation regime to a root development regime.

INTRODUCTION

Adventitious root formation on cuttings is influenced by the age of the stock plant. The effect of stock plant maturity on rooting of cuttings is widely known. Studies with ivy have shown that cuttings taken from plants with juvenile morphology will root easily but cuttings from plants of flowering age have a much reduced ability to root (Hackett, 1988). Similarly, cuttings from eucalypt seedlings or basal coppice growth root easily whereas shoots taken from the crown of a mature tree will root poorly or not at all (Paton et al., 1981).

Root formation on cuttings of woody plants is also influenced by the age of the shoots of the stock plant. Staff in nurseries cloning eucalypts for forest plantations in the Congo, Brazil, and South Africa collect cuttings when the shoots on the stock plants are approximately 8 to 10 weeks old (Chaperon and Quillet, 1977; Adendorff and Schon, 1991). Although this technique is common, there is little published evidence of the responsiveness of rooting to differences in shoot age. Part of the trial reported here investigated the impact of shoot age on rooting cuttings of *Eucalyptus grandis*.

Movement of cuttings from a misting to a watering and fertilizing environment should be done once primary root initiation is complete. To assist in defining the time of this event, our studies closely monitored root development.

MATERIALS AND METHODS

The experiment was conducted in the spring of 1989 at the Plant Culture Facility, the Australian National University, Canberra. Stock plants were of a single clone

of *E. grandis* and in the two years since their establishment as rooted cuttings they had been hedged at regular intervals to encourage multiple shoot formation on a central stem 30 cm high. They were grown in containers in a glasshouse with an air temperature maintained at 25°C day and 15°C night and received natural light and photoperiod.

Forty stock plants were used. The age of the shoots taken for use as cuttings was organized by firstly removing all shoots except one which remained as a lateral feeder shoot. As soon as axillary shoots had developed on the main stem the feeder shoot was removed. All the cuttings were taken at the one time from plants which had been hedged either 8 or 16 weeks previously. Twenty stock plants were hedged for each treatment.

The cuttings were prepared as four-node cuttings. On each cutting the two basal leaf pairs were removed, while the upper pairs had the leaf area reduced by 50%. The base of each cutting was treated with IBA (80 mg/liter in ethanol) for 10 seconds and then allowed to dry. Cuttings were inserted into Kwik pot trays with 42 cells, each of 70 ml and filled with a medium containing 1 peat, 1 perlite, and 1 sand (by volume). Four hundred and forty cuttings were arranged in pairs, each consisting of an 8- and a 16-week-old shoot. There were thus 220 pairs randomly set throughout a single block of trays.

The trays of cuttings were placed in the propagation facility under a misting system which operated for 5 sec every 5 min. Air temperature was in the range 20 to 30°C and the trays were set on a sand bed heated to 20°C.

Each week for 9 weeks and in the 11th and 13th week, 20 pairs of cuttings were selected at random, harvested, and the following features recorded: (1) the number of primary roots, (2) the dry weight of the root mass, (3) the number of original leaves retained, and (4) whether the cutting was alive or dead. A dead cutting was defined as showing no green pigmentation in the stem or leaves.

RESULTS

There were differences between the shoot types in the number of cuttings with roots, the number of primary roots produced, the weight of the roots, the retention of leaves and death of the cuttings.

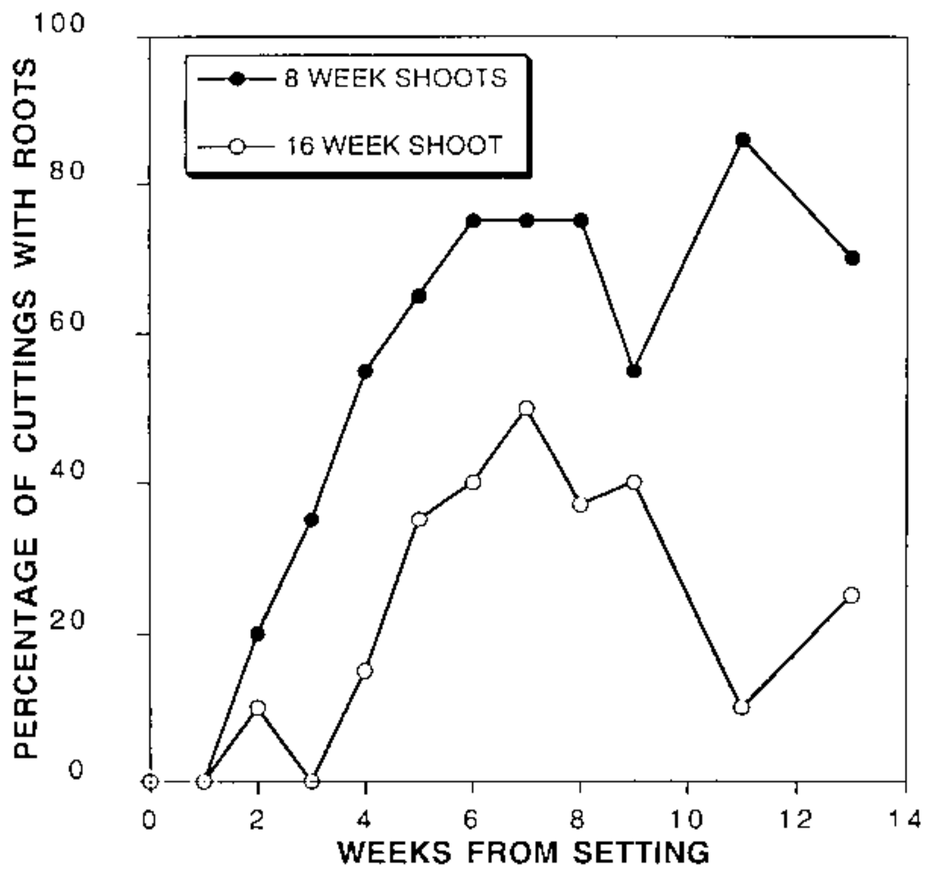

Figure 1. The percentage of cuttings to form roots.

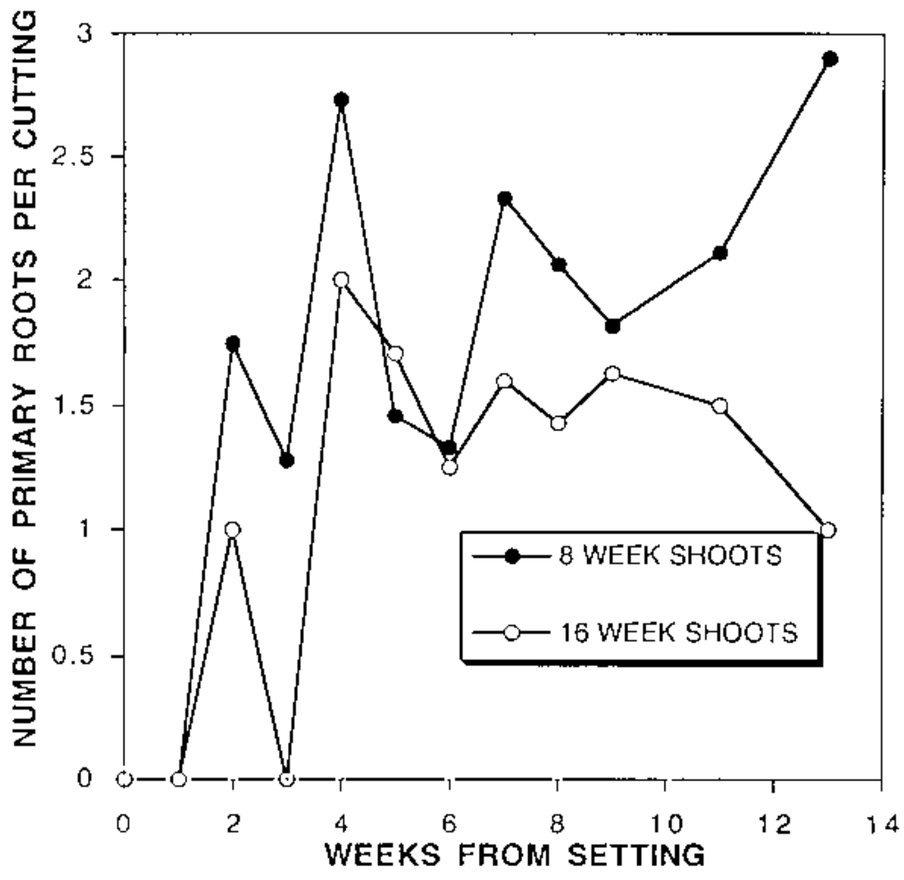

Figure 2. The number of primary roots per cutting.

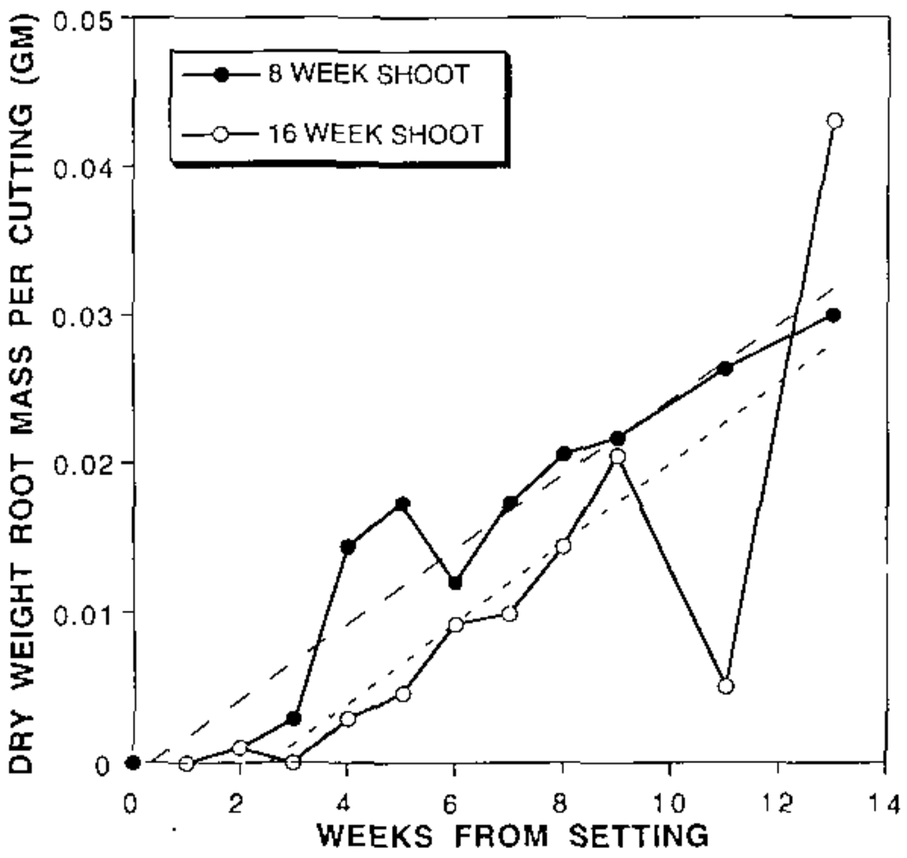

Figure 3. The dry weight root mass per cutting.

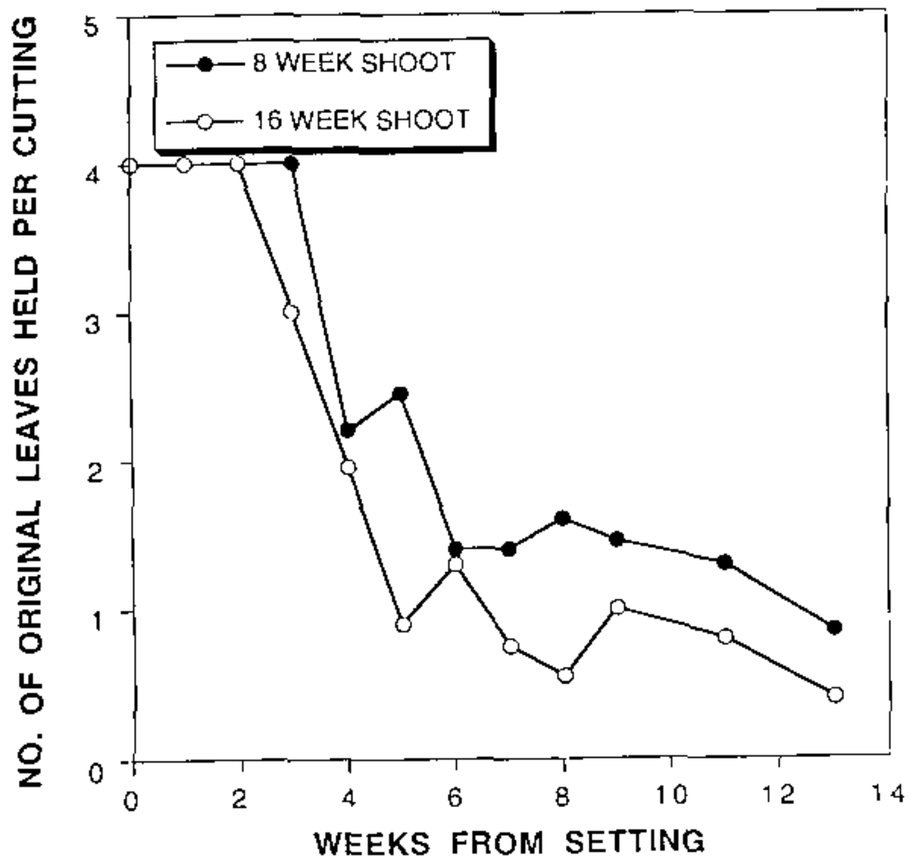

Figure 4. The number of leaves retained on each cutting.

The number of harvested cuttings with roots increased until week seven (Fig. 1). At that time 75% of the 8-week shoots had rooted but only 50% of the 16-week shoots had done so.

Primary roots were visible by the 2nd week after setting and they continued to increase in number per cutting until the 4th week (Fig. 2). After that time no new primary roots formed and root development continued as secondary roots.

The number of primary roots was greater on the 8-week shoots than on the 16-week shoots; the respective means at the 4th week were 2.7 and 2.0 (Fig. 2). Also, the root mass on the younger shoots was almost five times that of the older, suggesting that roots on the younger stems have been initiated earlier (Fig. 3).

Leaf abscission was more rapid on the cuttings from the older shoots (Fig. 4). These showed yellowing of leaves by week 2 and had retained only one of the original four leaves by week 5. The cuttings from the younger shoots also lost leaves but always retained more than did the older shoots. This leaf drop was due to senescence, as the leaves turned yellow and abscised.

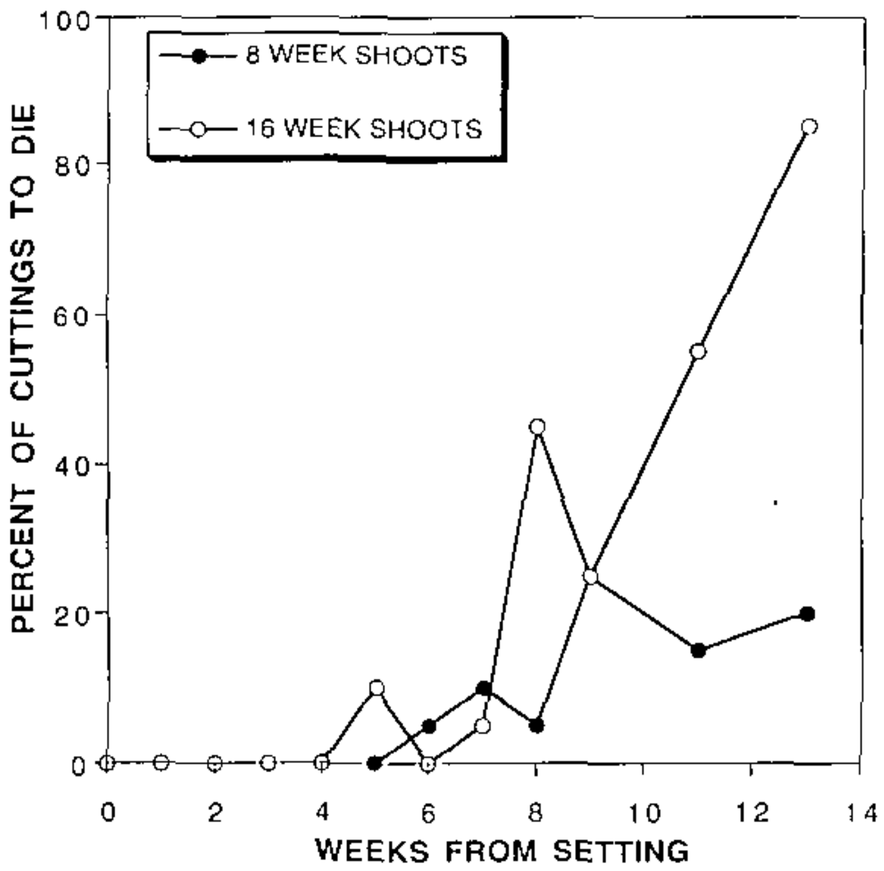

Figure 5. Percentage of cuttings to die.

The cuttings taken from 16-week shoots showed a higher mortality than their 8-week counterparts (Fig. 5). Cuttings of both groups had begun to die within 6 weeks from setting, and at week eight, 5% of the 8-week shoots and 50% of the 16-week shoots had died. At the time of the final observation, 13 weeks from setting, 20% of cuttings from 8 week shoots, and 80 % of the 16 week shoots were dead. The cuttings that died were leafless and over 90% did not have roots.

DISCUSSION

Cuttings from 16-week-old shoots showed a reduced ability to form adventitious roots compared to those from 8-week-old shoots. The older shoots produced fewer successful cuttings and those that were produced had fewer and smaller roots than those from the younger shoots. The cuttings from the older shoots also lost their leaves more rapidly than did those from the younger shoots.

Reasons for the reduced rooting behavior may include differences in shoot morphology and physiology. Haissig (1974) suggested that for some woody species, older stems with more differentiated tissues contain fewer root initiation sites. They may also have bands of sclerenchymatous tissue which act as a barrier to root primordia emergence (Williams et al., 1984). Also, they can have strongly suberized epidermal tissues and this may make the shoots less responsive to exogenous applications of auxin (Maynard and Bassuk, 1988). Younger shoots have less pigmentation and more succulent stems, features which are also characteristic of etiolated shoots of *E. grandis*, shown to be more responsive to adventitious root formation than non-etiolated shoots (Carter and Slee, 1991).

Shoot physiology is important in the rooting process. Variations in the absolute amount and ratio of carbohydrate and nitrogen pools in the leaf and stem tissues influence root formation (Haissig, 1986). Root promoters, inhibitors, and cofactors also vary with leaf age and undoubtedly a part of the response in our trials was due to those variations.

The differences in the rate of leaf senescence may explain the different rooting behavior of the 8- and 16-week-old shoots. Bachelard and Stowe (1963) reported that *E.camaldulensis* cuttings without leaves did not root and Geary and Harding (1984) also working with *E. camaldulensis* demonstrated that removal of more than 75% of the leaves from 4-leaf cuttings reduced rooting of these cuttings. In our trials it is possible that cuttings that had not developed root initials in the short period when leaves were fully functional were unable to do so after commencement of leaf senescence. This suggests that for optimal rooting response, shoot age must be such that the cutting will have leaves that are fully functional and will remain so for the duration of the propagation phase. Furthermore even basal segments of young shoots should be avoided if leaves are likely to senesce. Our trial has confirmed nursery practices for cutting propagation of *E. grandis* in Brazil and South Africa where 8-week-old shoots rather than older are used as cuttings.

The study has also provided guidelines for the schedule of operations. Primary root formation and emergence were completed within 4 weeks from setting the younger shoots. Therefore, cuttings at that time can be moved from an environment favoring root initiation to one encouraging root growth. High frequency misting could be replaced by a watering programme and fertilizer applied via the irrigation system.

By the 8th week from setting the cuttings, the propagation phase can be considered complete as potentially rootable cuttings have done so. After this time the rooted cuttings can be moved fully into the growing-on phase. These recommendations are in accordance with nursery practices observed by us in South Africa.

The results also provide practical guidelines for the assessment of rooting of cuttings of species with a pattern of adventitious root formation similar to *E. grandis*. Selection of species and clones for their rooting capacity as cuttings is based on criteria such as percent rooting, root numbers, and root mass. In the trial reported here, the first two of these criteria were fully expressed within 6 to 8 weeks of setting the cuttings, suggesting that assessment of rooting patterns can be carried out with accuracy at that time.

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Propagation of Rainforest Plants

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INTRODUCTION

As rainforests diminish, Public interest in growing them increases. This interest falls into three categories:

- Small-scale, usually urban, garden culture
- Landscaping
- Regeneration of forests

Vegetative propagation is used extensively for certain commonly grown species, such as some of the lillypillies, and the procedures used in such cases do not differ markedly from those used in producing more familiar plants (many of which are rainforest plants in their countries of origin). Many of the nursery techniques used to grow-on rainforest plants are familiar to most growers.

However, propagation of rainforest plants by seed is a relatively unknown field. Most rainforest plants in specialist nurseries are currently grown from seed, for a number of reasons:

- Where seed is readily available, large numbers can be grown economically.
- Many species are not easily propagated from cuttings, or little cutting material is available on stock plants.
- Root systems are stronger on many seed-grown plants than on plants produced from cuttings.
- Many growers are aware of the need to maintain the genetic diversity of a relatively small resource.

PROBLEMS

The problems involved in growing rainforest trees from seed accounts for the small, family-based size of rainforest nurseries:

- Seed is hard to locate, and where it can be found it may be difficult to access or illegal to collect, e.g. national parks. Commercial seed suppliers stock only a small range of the more easily stored species.
- Seeds are often viable for only a short period of time—in some species, seeds are viable for only a few days.
- Viability varies greatly not only between individuals, but between seasons.
- Seed production often varies annually, and massed fruiting of some species in some years may mean no fruit on those species the next year.
- Germination of many species is complex and requires labour-intensive and even painful processes. Some species such as the useful pioneer, crow's ash *(Pentaceras australis)* or the hardy coastal plant, beachacronychia *(Acronychia imperforata)* remain almost impossible to propagate.

GENERAL PRINCIPLES FOR SEEDLING PRODUCTION

Seed Collection. Collection by the grower is usually the only option for seed not available from the larger seed suppliers. As yet there are few small scale and botanically knowledgeable seed collectors who can provide adequate amounts of fresh, viable, correctly identified rainforest seed.

Seed is collected mainly from rainforest remnants, isolated plants on private property, or on roadsides in areas previously supporting rainforest, e.g. the northern rivers area of NSW. These are the best sources as plants are low, accessible, and fruit heavily in open conditions.

Collection from forested areas is more difficult as these are generally distant from nurseries, and the plants are either very tall or heavily shaded, hence producing few obtainable or uninfested fruits. Some growers with flexible morals frequently dig up wildlings, especially those of rare and endangered species.

Establishment of stock plants for rainforest nurseries is essential. For some species this may be a long-term project.

Collection of seeds from birds is a significant source that can be managed, e.g. by providing fruit trays to attract fruit eaters, with trays below to collect regurgitated seeds and droppings.

Seed Treatment. Processing immediately after collection is necessary for most seeds. Soaking in water for at least 24 h drowns seed predators and rehydrates any slightly dried but healthy seed. Dry capsules should not be soaked.

Removal of outer flesh is preferable, and in some cases obligatory, as in the case of most Lauraceae, such as the scented Oliver's sassafras *(Cinnamomum oliveri).* Soft flesh and capsules harbour insects which may destroy seed and may contain compounds which inhibit germination of seed. This necessitates laborious peeling, soaking to soften flesh, sieving and/or blasting with water, and, in a few cases, protection of hands against toxins (cunjevoi,*Alocasia macrorrhiza* var.*brisbanensis*) or fine spines (foambark, *Jagera pseudorhus).*

Initial drying for a few days is required in some species, particularly the Sapindaceae family, to assist removal of capsules or follicles. Care should be taken to prevent overheating when drying black seeds in full sun.

Seeds with hard seed coats, such as snowwood *(Pararchidendron pruinosum)* may need to be scarified. Heat treatment is rarely used as rainforest plants have no ecological connection between fire and germination.

Some of the most important species, especially the pioneer species with long-lived seeds such as brown currajong *(Commersonia bartramia)* and red ash *(Alphitonia excelsa)* as well as some mature stage species like white beech*(Gmelina leichhardtii)* and blue quandong (*Elaeocarpus angustifolius* [syn. *E. grandis*]), require idiosyncratic multiple processes.

Seeds with hard inner stones (e.g. red olive plum, *Cassine australis)* are a particular problem, usually requiring time-consuming treatment of rasping or cutting.

Germination and Growing-on. Germination times vary from a few days for peanut tree *(Sterculia quadrifida)* to 10 years for crabapple *(Schizomeria ovata*). Most pre-sowing treatment is an attempt to hasten germination times. For long-term germinating seeds, dense sowing (up to 3000 seeds in a standard propagation

tray for some species) and oversowing saves space.

Management of germinating plants (e.g. housing, ventilation, watering, control of fungus and seed predators) is similar to that in production of other nursery species. However, the combination of extraordinary diversity, short seed viability, and irregular seed production of Australian rainforest plants requires unorthodox methods. The solution is seedling storage instead of seed storage.

Seedlings are germinated in coarse sand, gravel or other free-draining, inert, nutrient-free medium. Fine seed, such as that which habitually germinates on tree ferns, may require addition of fibrous material to the medium. After the nutrients available in the cotyledons are exhausted the seedlings cease growth and will survive indefinitely with only adequate water, and minimal pest, disease, or fungal control (usually none). This response reflects the natural strategy of rainforest seedlings in forest conditions. In contrast with most sclerophyllous Australian species, rainforest plants can tolerate overcrowding and lack of fertilizer without root deformation, damping-off, or over-growing. This offsets to some extent the unsatisfactory storage capabilities of rainforest seeds. Nutrients are added preferably some weeks prior to potting up so that the plant is induced to break its dormancy and begin active growth. No long-term effects have been observed from the initial inhibition of growth, although more research should be done on this aspect. At potting up, tap roots, if present, are heavily pruned to induce lateral growth. Tap roots do not persist in rainforest trees under natural conditions.

Growing-on techniques are standard as for other acid-loving ornamentals. Contrary to many prejudices, most rainforest plants, with the exception of the understory species which may require 50% shade, are proving to be fast-growing in the nursery and hardy in full sun.

CONCLUSION

Public interest in rainforest plants is growing steadily, but is not being matched by enough research either into the species and forms most suitable, or the best techniques for producing them. With only a limited amount of accessible seed available at present, it is important that losses due to ignorance of the correct seed treatment should be avoided. Very little information has been written about rainforest seedling production, although it is likely that there is a great deal of empirical knowledge on the subject. Many of the problems could be overcome with more dissemination of propagation techniques, an efficient seed-swapping network and more serious research into growing of rainforest plants, particularly for much needed large-scale reforestation projects.

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Grafting Techniques

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INTRODUCTION

Propagators have been grafting for thousands of years.

When I first wanted to learn to graft I obtained Hartmann and Kester's book on plant propagation and studied the pictures. This book and Garner's Handbook of Grafting are invaluable texts on the theory and styles of grafting. However after reading these books I was still not able to correctly complete a successful graft. What I needed was a detailed description of how to physically graft. That is the carpentry of grafting, as well as the reasons why. I then sought out any local propagators who would show in detail how they grafted. There were few who were willing to divulge their methods. After much trial and effort I developed a method that allowed me to make an income from contract grafting. I believe that the practical techniques used in grafting should be documented as well as the theory.

GOALS

To make a wage through contracting your grafting ability, you need to achieve a high success rate and speed. You need a high success rate if you are to get future work. Your reputation depends on the last job. Success depends most importantly on the quality of the understocks and scion material. Grafting carpentry is but one step and at times the success or failure of grafts is beyond your control. This is where experience in plant culture is a great asset and is the difference between a person who can graft and a grafter.

Speed is needed to give the client value for money. Much of contract grafting is done on a piece rate basis and here speed is needed for the grafter to earn a worthwhile income. Some plants have only a short time when grafting is possible and being able to graft quickly will mean maximum takes. The aim of any beginning grafter is to find a method that will allow the seemingly opposite goals of speed and accuracy to coincide. For each grafter there seems to be an individual method. I do not claim to have the best method, only one that has been successful for me. I would advise young grafters to concentrate on accuracy first and allow their speed to build up with time. Aim at initially completing 200 grafts a day.

Most of my grafting has been done in nurseries on a bench and with container-grown stock. My preferred graft is a whip and tongue. This is a strong union and allows for good success as well as a quality graft.

Grafting is best when at least two people are involved. One person is needed to move and paint trees; the other does the grafting. It should be possible for one mover to keep stock up to three grafters. The advantage of this system is that the grafter is not required to have contact with the pot media. The working space can be organized for maximum efficiency and the risk of disease from contaminated pot media minimized.

GRAFTING

Equipment. The tools of trade for a grafter are few. It is unwise to skimp when purchasing grafting equipment as only a few percent increase in efficiency becomes a sizeable increase in income over a weeks effort.

Secateurs. Look for secateurs with the following features, replaceable blades, light weight, high quality steel, easily adjustable tension and easy to dismantle for cleaning. Price is a good indicator of quality.

Grafting Knives. These need to be of high quality, with thin strong blades and able to be honed to a fine edge. Light weight is also an advantage.

Grafting Tape. For soft plant material try parafilm. It is easy to tie, will break down in sunlight, and eliminates the need for grafting mastic. For harder wood use PVC tape. This will tie the scion tightly to the understock. I have found that the embossed tape is easier to grip especially in wet conditions.

THE CARPENTRY OF GRAFTING

Grafting is a repetitive task that requires a high degree of accuracy. To become skilled it is essential to eliminate all unnecessary movements. Arrangement of the work place is important. Take time to set up scion material, knives etc. so that they are within easy reach. A little extra time in setting up will bring a large increase in efficiency.

Holding the Knife. The way in which you hold your knife is critical for accurate cuts. The knife should be held with a relaxed grip. Clasping the knife tightly is difficult to maintain over many hours. Repetitive strain injuries will be eliminated if your hand is relaxed. I hold the knife with my thumb extended and index finger wrapped around the blade. The wrist is twisted so that the thumb is in line with your arm. Try to relax the fingers and only lightly grip the handle. It feels awkward at first but is not difficult with a little practice.

To gain success in grafting you will need to be able to make many cuts very accurately. To do this it is necessary to restrict and control your arm movements.

Cutting. There are two basic types of cuts used in grafting—the slice cut and the cross cut. Most grafts can be mastered using these cuts.

With the slice cut. Gently draw the blade along, allowing the knife to slice through the plant material. Depend on your blade's sharpness to do the work rather than physical effort on your behalf. Aim to have all the blade involved in the cut. This cut is made using your elbow and shoulder to pull the knife. Do not move either your fingers or your wrist. The length of the cut is determined by the angle of the blade. To make your cuts longer flatten the knife to be more parallel with the plant material. The cut should of course be the same length for both the scion and understock. A whip graft is the result of the scion and understock being sliced.

In the cross cut. Hold the knife in a similar fashion to that used for making a slice, but with the back of your hand facing you. Rotate your arm and therefore the knife using the thumb as a pivot. If the cut is not deep enough rotate the knife back. An important feature of the cross cut is to ensure that your hands are joined. If the knife slips or the wood splits it is difficult to cut yourself. A whip and tongue is created when the scion and understock are sliced and cross cut. Aim at doing this with four movements.

Tying Off. There are many ways to tie grafting tape. I usually start at the middle of the union. I then wrap down to below and then up to above the union. To tie off I return to the middle. A simple hitch is all that is necessary. It is important to be able to apply tension to the tape at all times during the grafting process. I have found that embossed tape is easier to use than is smooth tape, especially in wet weather.

Some Common Faults. We all fall into bad habits in grafting. Be aware and look to correcting these before they become serious.

Scooping. This is caused by a forward wrist movement and is usually associated with a tightening of the grip.

Tails. Usually caused by a movement in the non-cutting hand. This can also be a result of forcing the knife through rather than allowing it to slide. This is a difficult fault to correct.

Twisted cuts. These result from a rotation of your arm usually at the wrist.

Cuts not long enough. This is a result of not laying the knife flat enough. To overcome this make the knife blade and the plant material more in line.

SOME CONCLUDING TIPS

Buy at least two knives, preferably three or four. You will then not have to stop and clean a knife if one becomes contaminated or blunt. Plants showing a brown streak are usually diseased and should be discarded.

- Tie grafting tape around your neck and you will know where it is. Tape will easily pick up contamination if placed flat on a bench.
- Speed is more important than 100% accuracy. To increase speed develop a routine when grafting. Be careful not to develop useless movements.
- If possible, hold the grafting knife in your hand at all times. I hold mine in one little finger. A light grafting knife is necessary here.
- Take time to have everything at an easy height.
- And don't forget to hold your tongue—right!

Collection and Evaluation of Australian Plants

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INTRODUCTION

New Plants for Horticulture. Many countries, including Australia, have beautiful native plants that have never been brought into cultivation. Australia has a particularly large range including flowering trees; shrubs—both large and small; ground cover plants; climbers; bulbs; herbaceous perennials and annuals; and potential indoor foliage and flowering pot plants, and cut flower crops. Only a relatively small, although increasing number, of these have as yet received the hobbyists' attention, much less that of nurserymen.

Annuals and Herbaceous Perennials. Our rich range of annuals and herbaceous perennials is even less known and collected than are the woody plants. These plants respond remarkably to cultivation. In nature, the size and persistence of many of these plants is governed by the availability of moisture. The better the season the larger and more persistent the plants. However, plants rapidly hay off and disappear when moisture runs out. In cultivation on the coast, some of these species have continued to grow and flower for a whole year.

While it is easy to dismiss many of these plants as specialized desert species, it should be noted that the popular introduced *Gaillardia* and *Eschscholzia*—which perform very colourfully—are very much desert plants in their homeland.

The first step in the collection and evaluation of Australian plants is to locate plants that may be worth collecting and evaluating. Australia is a big country containing several thousand beautiful plants with exciting horticultural potential. Floras and other books are available that cover most areas. These are very helpful in gaining a knowledge about plants and where to look. Arid area plants are generally best located on the roadside, where the best plant growth results from the minute amount of extra moisture from road runoff. Gaining access to rainforest plants generally involves rugged mountain hiking.

COLLECTION

Serious collection of Australian plants involves many thousands of kilometers of travel. It also requires patience, perseverance, and a deep interest in native plants, not just the more flamboyant plants such as *Grevillea* or *Verticordia*, but all types from the diminutive to the large. You also need to know where and how they grow.

You need to be able to recognize plants and changes in roadside vegetation while travelling at 100 kph, to enjoy long hours of driving on quiet-roads, and to tolerate heat and dust or rain and mud. You need the patience to stop frequently and look thoroughly at plants. You need perseverance to keep searching, if necessary year after year, to relocate plants which appear only every few years.

Soils contain large numbers of seeds, accumulated over many years. A few weeks difference in the timing of rainfall can mean the appearance or non-appearance of some plants. A good knowledge of plant families is essential for successful plant

collection. Additionally, the collector needs to develop an ability to recognize horticultural potential for such uses as cut flowers or foliage, groundcover or bedding, pot or basket, or as a garden shrub or tree.

Anyone can recognize a beautiful flowering plant but it may have a great deal less horticultural potential than other far less spectacular plants that are much easier to grow or that are in flower more frequently or for much longer.

EVALUATION

Having located interesting plants, it is then a challenge to collect propagation material and to get it home alive. It is necessary to propagate the collected plants and to evaluate them under ordinary garden conditions. Assess potential in the wild but evaluate in cultivation. Some plants, because they don't respond to cultivation, respond vegetatively but flower poorly, or attract pests and diseases, have to be discarded.

PROPAGATION

Seed. Seed is usually easy material to collect—if you are there at the right time. Generally you are too early or too late. The seed of some plants, such as the outstanding eremophilas, is usually easy to collect but virtually useless because it is extremely difficult to germinate. Some species have at least three barriers to germination. Examples are a physical barrier in the form of a hard inner stone, a chemical barrier that has to leach away and a temperature barrier. Research into the germination of one species showed that seed that has lain more than 2 years in the soil would germinate only after substantial winter rain. Plants of the daisy family will often provide a few seeds from mature flower heads. *Ptilotus* and *Gomphrena* will sometimes also oblige. Hard seeds of plants such as *Crotalaria* and *Erythrina* can sometimes be salvaged by sifting the sand or gravel under mature plants. Scrapings of litter from under some plants have a good chance of yielding a few seedlings. Seeds of some plants take several years to germinate. For example, seed of the rainforest tree *Aceratium ferrugineum* have on three occasions germinated for me 4 years after planting.

Some arid-area seeds will germinate at a precise time (usually autumn), irrespective of when planted.

When you collect seed, except for most rainforest seeds, always collect into paper bags or envelopes, not plastic. Seed collected into plastic bags can be killed by high levels of CO_2 or mould will grow on them if there is any moist material such as undried pods, leaves, or stems present.

Cuttings. Cuttings can be surprisingly successful even when taken from severely drought-affected plants, provided they are prepared and packed properly. Cuttings, particularly those with sticky leaves, tend to drop all leaves after being wrapped for a few days. I generally trim the selected cuttings at the time of collection. This reduces bulk and also reduces shock to the material compared with that when the cuttings are trimmed twice. The prepared cuttings are then rolled in wet newspaper, drained of free water, and rolled in a plastic bag. Styrofoam broccoli boxes are excellent for storage and transport because they seal tightly. If cuttings are going to be on the road for over a week, it is advisable to place ice in the box. The ice should be in a watertight container so that the water cannot flood the cuttings.

Needless to say, the cuttings should be planted up promptly on arrival home. You can't expect a high percentage of success, but usually you can raise enough plants to propagate more. Herbaceous perennial species are best propagated from basal cuttings. These are the thickened basal parts of stems; discard the thinner upper portions.

Hybridization. I believe that the future horticultural development of our native plants must necessarily involve hybridization. So many of our beautiful plants grow only under quite specialized soil and climate conditions. One of the aims of hybridization will be to broaden the cultural base of these plants and give us more adaptable and easily grown subjects.

The benefits of such hybrids are already illustrated in the range of easily-grown *Grevillea* hybrids in which our somewhat disease resistant and adaptable coastal species *G. banksii* figures as a parent. I am referring, of course, to such cultivars as 'Robyn Gordon', 'Mason's Hybrid' [syn. 'Ned Kelly'], 'Superb', 'Pink Surprise', 'Misty Pink', 'Sylvia', 'Majestic', and several others.

Hybridization should best be attempted after a thorough study of the characteristics and cultural eccentricities of all the species in a genus, the entire gene pool, so that desirable characteristics can be deliberately combined. Nevertheless, most of the increasing range of native plant cultivars offered in the trade are accidental or spontaneous hybrids. They have resulted from the growing of several species in close proximity. The kangaroo paw hybrids are the most notable exception; they were deliberately hybridized in an attempt to achieve plants with specific qualities.

There are some very attractive hybrids in other genera, but it is intriguing to imagine how much more might be achieved after a close study of an entire genus. Hybridization using extremely difficult-to-grow species might give us fascinatingly beautiful and easy-to-grow new garden plants.

Other Cultivars. New garden plants with characteristics, such as variegated foliage, new vegetative forms, or new flower colours, may also arise as sports and mutations in cultivated plants. New cultivars can also be produced by growing for several generations seedlings from outstanding individual plants.

Provenance Variations. In many genera knowledge about all the species that comprise the gene pool is quite limited. There is even less knowledge and understanding about the extreme variation that commonly exists within many species. This variation, provenance variations, occurs between different populations of a species in different parts of its natural distribution. Often such variations are most exaggerated in extreme habitats in a plant's range such as mountain tops or headlands. These variations usually breed true from seed as for example, for naturally occurring prostrate forms of a number of otherwise erect plants. There may also be different colour forms, superior flowering forms, more adaptable and easily grown forms in some provenances. All of these can be valuable tools in the hands of a hybridist, but someone still has to locate the variant provenance, recognize the potential, propagate the plant, and evaluate the virtues or faults of the new acquisition.

SUMMARY

There are several essential steps in the collection and evaluation of Australian plants. These are: locating the plants; collecting suitable propagation material; successful propagation; growing plants under normal cultural conditions; and then, evaluation for hardiness, performance, pest and disease susceptibility, and any tendency to become a weed.

If a plant shows promise, further collections may be warranted for a greater comparison of individuals. Increased hardiness, more attractive form, better flowering, and different shades of colour may be achievable by collecting other provenances.

Phosphorus and the Proteaceae

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Macadamia seedlings were grown at several phosphorus (P) levels (0, 0.5, 1, 2,4 and 8 mg l^{-1} in a constant liquid feed) at the pHs (4.7, 5.6 and 6.4) in a soilless potting media. The seedlings responded strongly to P at the lowest pH. Increasing pH reduced growth and response to P. Possible reasons for the growth reductions are discussed.

LITERATURE REVIEW

The practice of preplant incorporation of superphosphate into container media containing soil was continued after the introduction of soilless container media which did not "fix" the phosphate in water-insoluble form. Yeager and Wright (1982) showed that following incorporation of superphosphate into soilless potting media the phosphorus (P) concentrations can be as high as 248 mg/liter in the weeks following potting. This level is likely to cause problems of iron deficiency for most plants. Handreck (1990) has stated that soluble P in a 1 : 1.5 D.T.P.A. extract should not exceed 3 ppm for young plants of a sensitive species. This is equivalent to 15 ppm in the water in a container. He has since confirmed this for *Banksia* species (Handreck 1991).

Following from the work of Grundon (1972) and Nicholls and Beardsell (1981) there developed in the nursery industry the idea that most Australian native plants and particularly the Proteaceae did not require any phosphorus fertilizer. Manufacturers of slow-release fertilizer responded by developing products with either no P or very low levels of P.

Recently Bowden (1987) challenged the concept that Proteaceae should not be supplied with phosphorus and concluded that Proteaceae did respond to phosphorus. What should be said is that plants in the Proteaceae family are sensitive to phosphorus when it is applied in the wrong form and at the wrong concentration.

Because growing macadamia seedlings is a large and important industry in the Alstonville area, we initiated a project to look at the response of macadamia to both phosphorus and pH in an effort to improve growth rates.

MATERIALS AND METHODS

Macadamia seed from the variety H2 (Hinde) were germinated in sand. At the four-leaf stage they were transplanted into a 5 litre planter bag containing a soilless potting mix consisting of 35% composted hardwood sawdust, 35% composted pine bark fines and 30% coarse river sand. It was amended with slow-release fertilizer with no P at 2 kg/m^3 and Micromax at 1 kg/m^3. The slow-release fertilizer was

applied every 3 months. The mix had a pH of 4.7. Two additional pH treatments were created by adding 100 g and 400 g of dolomite to each 30 liters of mix. This produced pHs of 5.6 and 6.4 (1 : 1.5, by volume in water).

The phosphorus treatments were applied as phosphoric acid (H_3PO_4) at the following levels: 0, 0.5, 1.0, 2.0, 4.0, and 8.0 mg/liter in 500 ml of water applied every second day. This replenished the soil solution and flushed the pots, keeping P levels constant. There were five replications and the plants were grown in an evaporatively cooled glasshouse.

Plant height was measured monthly and at harvest which was after 9 months of growth. At the conclusion, the plants were cut and dried and root, stem and leaf weights recorded.

RESULTS AND DISCUSSION

Growth was significantly increased by P at the lowest pH while increasing pH both reduced growth and limited the response to P (Fig. 1).

Plants growing in the P_0 treatment developed characteristic symptoms on the lower leaves which we now believe to be phosphorus deficiency symptoms. These appeared initially on the oldest leaves as interveinal purpling on the upper surface. This progressed through the leaf, eventually becoming necrotic and coalescing.

Clearly macadamia seedling growth is promoted by P, provided it is not applied at excessively high rates. The P level at which growth would have been reduced was not indicated in this experiment. However, in a further experiment using rates up to 64 mg/liter of P, which is not yet complete, chlorosis appeared at and above 32 mg

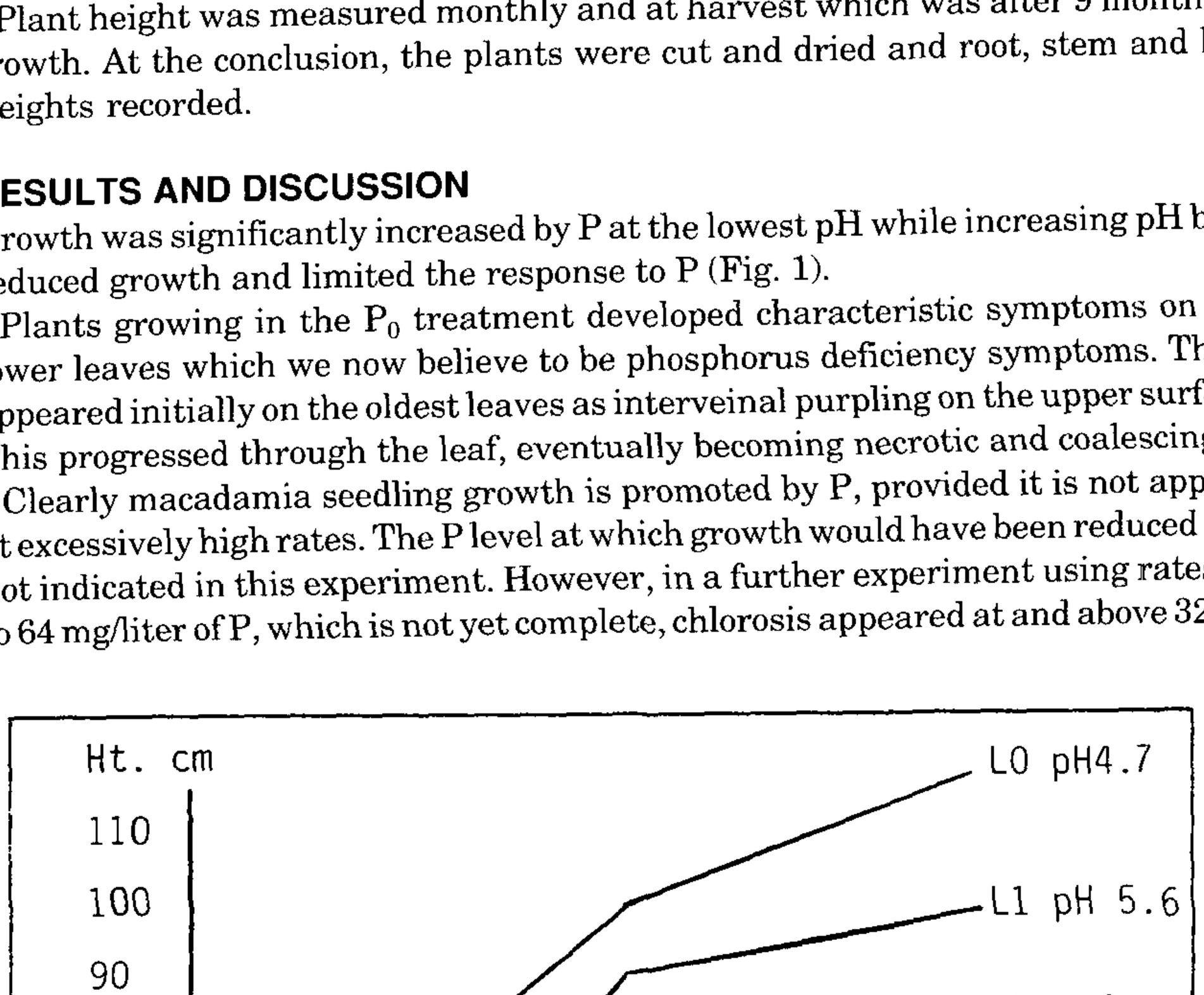

Figure 1. Effect at harvest of P and three lime rates on plant height.

at a pH of 4.7 and at 16 mg at a pH of 5.6 and 6.4. At the highest pH chlorosis is severe and growth is reduced. The reasons for the reduced growth and P response at the higher pHs are less clear. When plant analyses are completed it may be possible to state what caused the growth depression.

Aitken et al. (1990) in Queensland have demonstrated with macadamia that nut production and seedling growth are reduced at soil pH >5.5 (measured in water) which they ascribe to induced micronutrient deficiencies. The availability of iron is greatly reduced as pH is increased and increasing phosphate levels also reduce the availability of iron. Therefore, it is possible that the growth reduction resulted from iron deficiency, although the plants were not chlorotic.

We would like to suggest that members of the Proteaceae have an inefficient iron uptake mechanism and thus small changes in pH or P level can result in phosphate-induced iron deficiency which is more common than phosphate toxicity itself. Wright and Niemiera (1987) indicate that in soilless media the optimum pH range for maximum nutrient availability is 4.0 to 5.2 as manganese toxicity is unlikely.

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Fruit Tree Propagation

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INTRODUCTION

Nurserymen growing fruit trees generally need to become masters of a wide range of propagation methods and cloning techniques. The larger the range of plant types grown, the greater the number of propagation methods needed. Proficiency must be achieved in the following plant propagation methods used throughout the nursery industry: seedling, cuttings, marcotting (aerial layering), grafting, budding and to a lesser extent micropropagation (tissue culture).

For any fruit tree nursery to maintain commercial viability in today's competitive market place, an estimated 70% propagation success rate is required to break even, with the additional 30% providing the profit. In fact, success rates over 90% must be consistently achieved for long-term profitability and survival.

Seedling production is generally limited to rootstock production for future grafting although some*Carica* and*Passiflora* species. are field planted as seedlings. Polyembryonic *Mangifera* and *Garcinia* species. produce true-to-type nucellar seedlings.

Vegetative clonal propagation of selected cultivars is mandatory and constitutes over 95% to 100% of most fruit tree output. This is generally achieved by either grafting/budding onto genetically variable seedling rootstocks or using cuttings/marcotts from established parent orchard trees. Micropropagation is carried out by specialist laboratories producing *Musa*, *Carica,* and *Vaccinium* species.

ACHIEVING RELIABLE SUCCESSFUL FRUIT TREE PROPAGATION

All plant propagators have some level of natural ability that usually determines what type of plant they end up propagating. Traditionally, most plant propagators with grafting and/or budding ability usually end up in the fruit tree industry due to the high level of application of those skills in that field. For this reason, the following discussion will be limited to budding and grafting, although many of the general principles discussed can be used with propagation by seedling, cutting or marcotting.

Keep Good Records. To consistently achieve high success rates year after year, it is essential that accurate records be kept as follows:

- Plant genus and species
- Time of year and specific date
- Rootstock condition, maturity, and variety
- Rootstock sap flow
- Scion material condition, maturity, and variety
- Weather conditions—daily and seasonal temperature maximum and minimum.

- Daily humidity
- Daily rainfall
- Number of plants propagated
- Grafting tape and source
- Grafting tools used in operation
- Time of side shoot removal
- After care of plant post grafting
- Success rate of results
- Pest and disease influence

Accurate records enable us to learn from our failures. Remember, if only 1% success is achieved, the potential is there next time to attain 100% success.

Scion Selection and Time for Grafting. Understanding the physiology of your plant in relation to seasonal growth cycles is an essential part of scion selection. Generally, most fruit trees require some rest period to accumulate starches and store food reserves prior to flowering and fruiting. This occurs towards the end of winter for most sub-tropical and temperate fruits that are semi-deciduous or deciduous. The ideal time to graft is just prior to or at the beginning of sap flow in spring. There usually is a period of 10 to 30 days, depending on species and variety, when best results will be achieved. Often in cooler climates budding is carried out in late summer/ early autumn as sap flow slows down. Buds are allowed to remain dormant and rootstocks are cut back in spring to produce strong bud growth.

Rootstock Production. The results of grafting will be good only if rootstocks are healthy and with strong straight roots. Particular attention must be given to vegetative and root pathogens including viruses and nematodes with species such as *Persea*, *Citrus*, *Passiflora*, *Malus*, *Prunus,* and *Macadamia*.

With tropical plants, the rest period occurs during the dry season or between vegetative growth flushes although these may be short in the true wet tropics. Scion material is best collected towards the end of the rest period just before growth commences. This principle also applies to deciduous trees when summer greenstick grafting. Best budding or grafting results are achieved when scion material is selected at the end of the spring/early summer growth flush just prior to commencement of the mid-summer/summer growth period.

Stock/Scion Maturity. Where possible, closely match the maturity of rootstock and scion. Young rootstock in a green condition will readily accept either young or mature scion material. Mature hardwood rootstocks will accept mature scions only. Always avoid grafting young scion material onto old woody rootstocks. Remember "you can graft old or young into young but not young into old".

Do not Propagate Wet Plants. Accurate records over a 12-year period have shown over 99% of major losses have been attributed to budding or grafting during wet weather. Complete losses have been experienced when scion material was collected under wet conditions. When collecting and cutting scion material, be sure to abide by the following rules:

1) Never cut fully turgid scion material during wet weather or early in the morning when laden with dew. Best time to collect material is 10:00 a.m. to 4:00 p.m. or 24 h after the last rainy day. Be sure to quickly remove leaves if scion material is collected during hot dry conditions so as to prevent desiccation.

2) Never graft/bud wet rootstocks.

Bad failures can often be attributed to one of the above, especially (1), when also applied to cuttings and marcotting. There are two main reasons:

1) Fully turgid tissue collected during wet conditions is bruised 5 to 10 cells into the cambium during the grafting operation. This discourages the growth of healthy callus tissue and encourages the development of bacterial soft rots within the graft union.

2) Scion material cut during the wet weather/early morning when fully turgid has stomata and stem lenticels in fully open positions. This encourages the material to lose moisture and desiccate during the healing period following grafting.

Grafting Operation. This is important and must be carried out precisely and correctly. If scion/rootstock maturity is similar, bark/cambium/cortex thickness will be the same and good results will be achieved.

When greenstick micro-grafting or when standard grafting or budding any tree during active growth, retain as much leaf as possible on the rootstock below the graft/bud union. This is important so that the newly developing root system is fed until the developing graft/bud commences growing and produces sufficient leaf to sustain rootstock growth.

Most fruit tree nurseries commonly bud using 'T' or chip buds. Whip (splice), cleft,, bark or side grafts are commonly also used. A top-side, half-cleft graft is gaining in popularity in many fruit tree nurseries. This graft is used extensively in Asia and Central America. It enables small scion material to be grafted to rootstocks 2 to 4 times thicker, as shown in Fig. 1.

Many fruit tree nurseries obtain rootstock seed and scion material sources through schemes where parent trees are tested for freedom from plant pathogens.

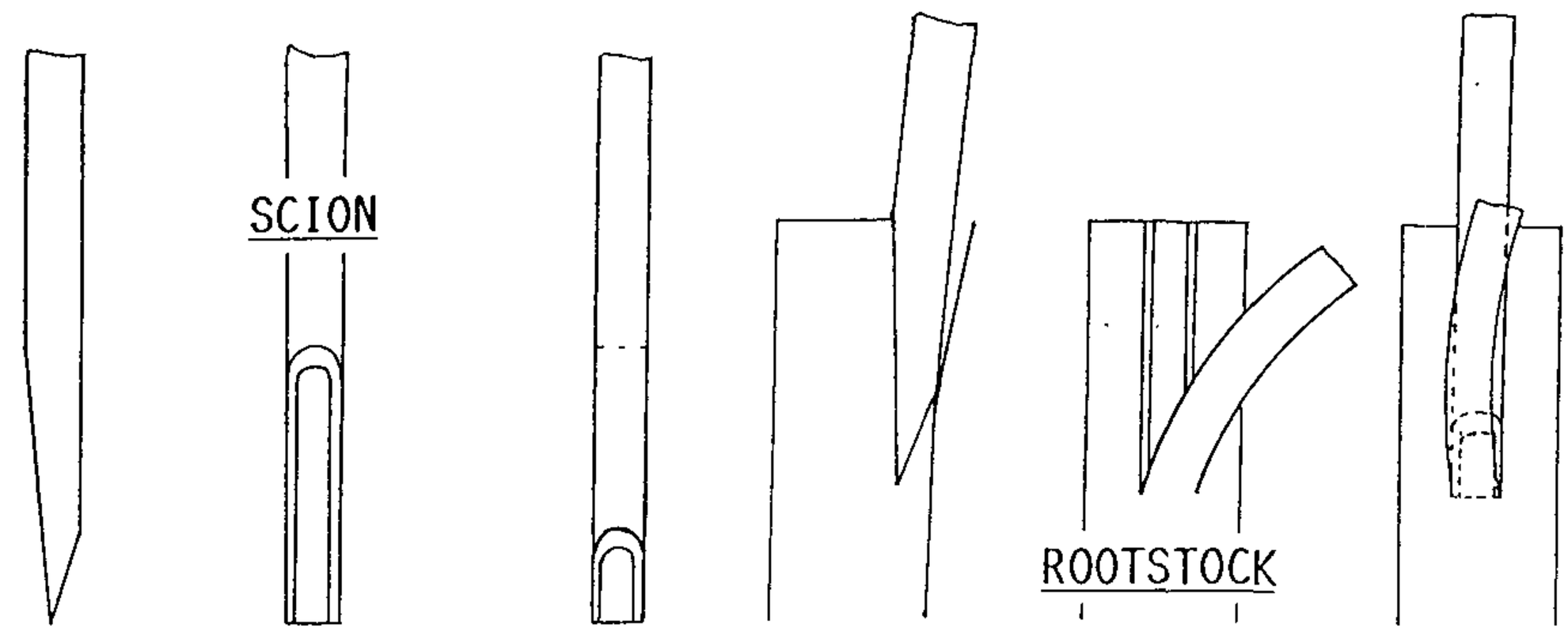

Figure 1. Top side cleft graft.

Also nursery clean-schemes where plants are container bench grown in steam pasteurized potting media and irrigated with chlorinated water ensures freedom from soil-borne pathogens and nematodes.

After Care Following Grafting. Protect newly grafted grafts/buds from:

- Free moisture for at least 2 to 14 days after propagation depending on grafting method used, irrigation system and climate.
- From heat in excess of 35°C by reducing light intensity by at least 30% of previous light intensity used for 10 to 21 days.
- Excessively low humidity—use opaque white plastic bags over grafts or put plant in plastic igloo to maintain optimum humidity levels depending on plant species and propagation technique used.

SUMMARY

In summary, the importance of each step in the production of a grafted/budded plant is as follows:

Operation	Importance (%)
Scion selection/time of grafting	50
Grafting operation/technique	20
After care	15
Rootstock production	15

Naturally, if any one of these steps is incorrect, failures will result. Selection of scion material for grafting or budding is the critical factor of success. The best grafter in the world will achieve poor results when using poorly selected scion material, regardless of his ability to graft.

REMEMBER

Trial + Error = Experience + Success

Be prepared to experiment and through accurate records turn failure into success.

Treatment of Plants with Hypochlorite Solutions

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Hypochlorite solutions are one of the cheapest and most effective disinfectants available to the nursery industry and one of the least harmful to treated plants. However, there seems be some confusion about concentrations, duration of treatment, and conditions for effective treatment. Part of this confusion might be due to differences in objectives by different users of hypochlorite treatments. The objectives in a micropropagation laboratory, for example, are quite different from those in nurseries using other propagation methods.

MICROPROPAGATION—DISINFECTING OBJECTIVES

The disinfecting objectives in the initiation of plant material into culture (commonly called Stage-I) are more demanding than in nurseries. The aim is to kill ALL microbes on the plant material WITHOUT killing the part of the plant to be placed in culture. Plant material harbors millions upon millions of microbes but the vast majority of these do the plant no harm. They are, however, a NUISANCE because many of them grow well on the food supply of the culture medium, they overgrow the explant in the culture vessel and, in the case of slow-growing bacteria, alter the chemical composition of the medium.

The methods used in micropropagation laboratories for the control of these NUISANCE microbes are mostly also effective against the other categories of microbes called PATHOGENS, that is, disease-producing organisms. It is important to realize that treatment of plant material with hypochlorite solutions alone is rarely sufficient to kill both NUISANCE and PATHOGENIC organisms. Micropropagation laboratories employ additional treatments such as growing mother plants in hygienic conditions, thorough cleaning of the plant material, washing in running water, removal of excess plant material, treatment with hypochlorite with added detergent and with agitation and/or with reduced pressure, dissection of growing points and further treatment with hypochlorite solutions (de Fossard, 1990). And we would still expect to get some cultures with microbial contamination.

OTHER METHODS OF PROPAGATION—DISINFECTING OBJECTIVES

When discussion turns from micropropagation to propagation by seeds, cuttings and budding, the key difference is that propagators need not be concerned with the numerous NUISANCE microbes which plague laboratories but, instead, must concentrate on PATHOGENS. And the first step is to learn what diseases affect the plants being propagated so as to recognize their symptoms in mother plants—THEN to destroy plants showing these symptoms. They should have no place in a *nursery's propagation schemes.*

Yes, we've done that, says the nurseryman, but we also want to do something with our propagation material in case the mother plants are carrying pathogens but are

symptom-less at the time we strike cuttings. Can we use hypochlorite solutions as a prophylactic measure?

Before trying to answer that question, it is necessary to examine more closely the properties of hypochlorite solutions.

HYPOCHLORITE SOLUTIONS

The cheapest form of hypochlorite is the one that comes as a powder and this is calcium hypochlorite. The author has avoided using this, first, because it can be dangerous to users if used carelessly, and, second, because it is more laborious to prepare as a solution. Instead, various proprietary brands (White King, Snow White, Clorox) of sodium hypochlorite solutions can be used, and the cheapest of these is "pool chlorine".

The stated concentrations of these types of hypochlorite varies and should be stated. as "%(w/v) available chlorine". Clorox is 5.25% (w/v) available chlorine, White King is 4%, and pool chlorine may be 10% or higher. The problem is that the stated (on the label) %(w/v) available chlorine is mostly higher than reality because the % available chlorine (even in tightly stoppered containers) decreases with time and decreases fastest with higher temperatures in storage (in the supermarket, for example). "Pool chlorine", purchased from swimming pool stores, is most often the "freshest" (that is, nearest to the stated concentration) because of high turnover in these stores.

Ideally, the concentration of hypochlorite solutions should be tested in the laboratory or nursery before use, and a method for doing this is described in de Fossard (1990). The standard hypochlorite treatment used in the author's laboratory is 1%(w/v) available chlorine for 20 min. If this is found to harm plant material, a 0.1% solution is used for 40 min, and other variations in procedure may be used. Pool chlorine, ostensibly with 10%(w/v) available chlorine, may have been purchased and, to prepare a 1% solution from this, a simple calculation is followed:

> Volume(ml){V-1} pool chlorine to be taken equals volume(ml){V-2} of 1%(C-2) required divided by % concentration {C-1} of pool chlorine, or:

$$\text{V-1} = \frac{\text{V-2} \times \text{C-2}}{\text{C-1}}$$

$$\text{V-1} = \frac{1000 \times 1}{10} = 100 \text{ ml}$$

Thus, take 100 ml of pool chlorine and add water to 1,000 ml to prepare 1,000 ml of 1% (w/v) available chlorine solution.

If, on testing, the ostensibly 10% pool chlorine it is found to have say, 9.5% (w/v) available chlorine, then the calculation would be:

$$\text{V-1} = \frac{1000 \times 1}{9.5} = 105 \text{ ml}$$

and, 105 ml of pool chlorine plus water to 1,000 ml would be used to prepare 1,000 ml of 1% (w/v) available chlorine solution.

ARE HYPOCHLORITE SOLUTIONS EFFECTIVE PROPHYLACTIC MEASURES IN PROPAGATION?

The effectiveness of hypochlorite solutions in killing microbes is a function of concentration (that is, % (w/v) available chlorine) and duration of treatment, or, in general terms, they are effective if they are STRONG ENOUGH and applied for LONG ENOUGH. A solution containing 1% (w/v) available chlorine applied for 20 min would probably be effective against a very wide range of microbes in THEIR VEGETATIVE form, but if SPORES of pathogens were present a minimum 4-h treatment would probably be required. And the story has to be qualified. In micropropagation, the hypochlorite treatments are effective when given with a number of other treatments and, in particular, with the prior cleaning and washing treatments.

CONCLUSIONS

Simply dipping plant material in hypochlorite solutions is unlikely to have a discernible effect on microbes on the plants so dipped. A dip in water alone may have the same beneficial effect (if, indeed, there is a beneficial effect) and hypochlorite in such water baths may then have a prophylactic role in regard to minimizing cross-contamination—the hypochlorite, if strong enough, would have the time to kill microbes in the dip.

But are hypochlorite solutions likely to be effective as far as pathogens are concerned in propagation? If the pathogen is in its vegetative mode, the answer is a qualified "maybe".

If the nurseryman cannot give this assurance, then the minimum 4-h treatments required may harm the propagating material, and there would be no guarantee of total kill of spores because some would have not been contacted by the hypochlorite. Internally situated pathogens, of course, would be in this latter category.

Hypochlorite solutions if strong enough and applied for long enough are likely to be as effective or even more effective than many other more complicated and expensive chemical treatments in general hygienic practices in nurseries. But against pathogens in stock plants, hypochlorite solutions would not be recommended by this author. Knowing one's plants, knowing the pathogens which they are susceptible to, taking measures to eliminate diseased stock, and isolating and protecting "tested" mother plants is the first line of defence against pathogens, not hypochlorite treatments.

LITERATURE CITED

de Fossard, R.A. 1990. Micropropagation. Xarma Pty. Ltd., P.O. Eagle Heights Queensland 4271 Pages vi + 320 accompanied by 16 files on floppy disks responding to LOTUS 123 commands.

Grevillea Propagation

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We have been producing grevilleas for a number of years. During that time we have used many different techniques to propagate them. In this paper I will discuss some of the techniques we are currently using to propagate grevilleas.

There is always something new to try and there are all the old standard rules to keep as well. Whenever we are forced to compromise these rules, we will have less successful propagation results or even total disasters. Two of the most important of these rules are, good, well-managed stock supply and a high regard to hygiene throughout all the propagation procedures.

Stockplants, for us are very important for two reasons. One reason is to ensure the availability of cutting material to cover the numbers of cuttings we need to put down for a batch. The other is to ensure that the quality of cutting material is high. We found it to be a difficult and expensive task to meet these two criteria as our nursery was only a propagation nursery with no containers from which to gather cuttings. We had an acre of stockplants at one stage as well as extensive gardens to supply cutting material. The work and upkeep of such a system was great. We now have a different system of providing cutting material which we feel is more effective for us. We now grow container lines and use the nursery as a source of cutting material which gives us high-quality, young, well-nourished cuttings from which a good strike rate is almost always achievable. In addition, we utilize public and private gardens, and other nurseries for a backup and for extra numbers. So we in effect have two sources of most stock requirements. Disadvantages of taking cuttings from containers are that you may need to sell containers or leave cutting material on the container plant to get it ready for a sales deadline.

Having established a good, reliable, and healthy source of cutting material the task of making cuttings efficiently and choosing the environmental conditions you need to put roots on as quickly as possible begins.

Many different techniques have been tried for making cuttings, but at present we are using cuttings of mature wood from current seasons growth using as clean a cut as possible and slightly scaring the side of the cutting. Leaf area is reduced and we have had encouraging results with some species in reducing the leaf area greatly.

Two contrasting techniques are used for different grevilleas. With *Grevillea* 'Poorinda Royal Mantle' and *G. asplenifolia,* we reduce leaf area and cutting size to a minimum. With *G.* 'Sandra Gordon', *G.* 'Honey Gem', and *G.* 'Moonlight', we find that larger cuttings carrying two to three nodes and leaves are more successful than single-node cuttings.

Another technique used for cuttings is to leave all the leaves on the stem. We used this method with *G. juniperina* 'Prostrata Red' to save the cutters from being spiked by the sharp leaves when stripping and we found the strike rate of these cuttings surprisingly good.

When making cuttings of grevilleas you must make any cuts to the stem as clean as possible. We usually ensure this by using budding knives. During this past year we have tried making grevillea cuttings using a tiny pair of secateurs. Results from

this technique have been adequate, although I prefer to use a budding knife.

One technique we have used on all cuttings, including grevilleas, is a very successful way of reducing the handling of individual cuttings. Instead of throwing cuttings into a pile as we make them up, we place them into slots that have been cut into a foam fruit box. The cuttings are held altogether with their ends ready to have hormone powder applied. The hormone powder is applied with a small paint brush, then a small bunch of cuttings can be removed from the box and dibbled into the prepared medium.

We put our cuttings on a heated bed with mist inside a polyhouse. After roots are formed, they are moved out into a shade house for hardening off and fertilized with liquid feed to encourage growth if it is needed.

An environmental aspect of propagating grevilleas which ties in with hygiene is the dilemma of how wet to keep the environment. We have found that grevillea cuttings must not be kept too wet with mist as they tend to be affected by fungal problems. Also, we have found that grevilleas prefer a light, open rooting mix with very good drainage.

Hydroponic Propagation of *Aglaonema*

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INTRODUCTION

We started to experiment with growing indoor plants hydroponically in 1978. We found best growth with *Aglaonema* 'Silver King', *A.* 'Silver Queen', *A.* 'Parrot Jungle', and *A. pseudobracteatum*.

Hydroponically grown *Aglaonema* are cheap to transport. As many as 250 (300 mm tall) plants can be packed into one carton. They can be kept, wrapped in peat moss in bundles of 10, for up to two weeks. The plants can be potted up at the other end and be ready for sale in approximately three months instead of a typical six months for saleable plants from cuttings.

HYDROPONIC PROPAGATION

The Subirrigation Gravel Unit. A commercial subirrigation system using 9-mm blue metal gravel as a substrate in a V-shaped trough is used. The unit has an inlet-outlet pipe running the full length of the trough to ensure excellent drainage. Good aeration is assured through the use of large (9 mm) gravel. Flooding occurs automatically every 2.5 h during daylight but only twice at night.

Formula (hydroponic nutrient solution) control is manual and a recirculating system is used to maintain economical use of nutrients and water.

Hygiene of Unit. It is important that the gravel is thoroughly washed so that no dust or limestone are left in it. The pipes from the media tank, the troughs, and the gravel should be sterilized with 1/100 formalin. The unit is thoroughly rinsed after a 24-h soak.

Provided the unit is kept clean, it may be used continuously for at least five years. All damaged plants, dropped leaves or diseased plants must be removed. After removing cuttings the gravel should be turned over and any broken roots removed. It is advisable to include 5 ppm Benlate in the solution as a preventative treatment in damp, overcast conditions.

The hydroponic unit that we use is situated in a propagation house which has forced-air ventilation, a temperature range of 20 to 30°C, 70% humidity, and good light (1200 ft-c). No misting is used in hydroculture and the solution temperature is 20 to 24°C. However, provided the solution temperature does not vary more than 4°C and the air temperature does not vary more than 15°C and the air temperature does not fall below 15°C, or exceed a range of 30°C daily, all cuttings perform well.

Hydroponic Nutrient Solution Formula

Macronutrients[1]

Macronutrient	Quantity (kg)
Monopotassium phosphate	0.454
Potassium nitrate	2.27
Calcium nitrate	3.54
Magnesium sulfate	1.42
Water to 3785 litres	

Trace Elements[2]

Trace element	Minimum (ppm)	Maximum (ppm)	Optimum (ppm)
Iron (Fe)	2.0	5.0	4.0
Manganese (Mn)	0.1	1.0	0.5
Copper (Cu)	0.01	0.1	0.05
Boron (B)	0.1	1.0	0.5
Zinc (Zn)	0.02	0.2	0.1
Molybdenum (Mo)	0.01	0.1	0.04

[1] The following gives (in ppm): N 190; P 34; K 275; Ca 52; Mg 45.
[2] Trace elements are added only after the water has been analyzed. Final concentrations in the solutions after analysis and addition of trace elements.

***Formula Notes*:**

1) The formula is used at half strength for propagation.
2) The chemicals must be weighed out accurately.
3) Careful storage and use of pure chemicals is of the utmost importance if you are mixing your own formula.
4) Use clean, filtered water.
5) Water should be adjusted to pH 7 before adding nutrients. Use phosphoric acid or dehydrated lime to adjust the pH.
6) Calcium nitrate is added separately.
7) Trace elements are best added via a stock solution; iron should be added separately.
8) Check pH and conductivity after mixing the formula.
9) Check all electrical and automatic systems for reliability and correct settings.
10) Prepare propagation material in clean, aseptic conditions.

Simple Formula Adjustments:

1) Add 28.3 g iron sulfate weekly (to 3785 litres).
2) After three weeks, to return pH and conductivity to normal, add another 10% of the weight of all macronutrients.
3) If plants do not progress at a normal rate on a steady pH, a 3.4 ppm phosphorus boost may be necessary.
4) If pH and conductivity are swinging or rising rapidly a new formula needs to be prepared and the old one replaced.
5) Benlate, 5 ppm in solution, is used in winter.
6) When using sprays, fungicides, etc., check for trace elements content before use in hydroponic solutions or toxicities will appear.
7) Remember there is no normal soil buffering effect in a hydroponic solution, so whatever is put in will be taken up by the plants.

MAINTENANCE

- Remove damaged plant material, spilled soil, etc; if gravel is soiled, remove, clean, and replace.
- Check time clocks and adjust if necessary.
- Top up nutrient solution with water.
- Do not increase irrigation times, even on very hot days. New cuttings may be misted every 6 to 48 hours if humidity is low.
- On a weekly basis, flood troughs to overflow and sprinkle cuttings. This removes any excess salts from the top 2.5 cm and prevents buildup of dust.

PROPAGATION OF *AGLAONEMA*

Stock plants should be healthy, free from disease and insect infestation, true-to-type, and vigorous. We grow our stock plants in 175-mm pots in a poly- covered house which is heated to 18°C minimum from the end of May to the end of September.

Cuttings are taken from August to May. We take a multi-noded cutting with three leaves or more. These are planted into the gravel (70 mm deep and spaced at 90 mm centres) with a dibbling tool.

Roots start appearing after two weeks. In summer the rooted plants take six weeks to grow big enough for despatch and in winter they take up to eight weeks.

Aglaonemas come from humid tropical areas in Thailand, Sri Lanka, Malaya, Philippines, China, and Indonesia. They are free branching and suckering plants that grow slowly and last for a number of years if given ample humidity. They make good house plants and are much used in indoor plant hire.

Assessment of Wetting Agents for Use in Nurseries

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Techniques for rapid evaluation of the short-term effectiveness of wetting agents and their longevity in nursery situations are described and authenticated. Propagation media need contain no more than 0.1 ml/liter of the most effective wetting agents tested.

INTRODUCTION

Wetting agents have been used to improve the wettability of water-repellent soils since the 1960s (Letey et al., 1962). Their use in potting media stems from reports by Sheldrake and Matkin (1971) and Airhart et al. (1978, 1980).

Reeker (1954) and Sheldrake and Matkin (1971) described methods for evaluating wettability involving a measurement of the time taken for dried peat placed on the surface of pure water in a beaker to become fully wet. An end point is difficult to gauge when bark is used as the test medium, so another method of evaluation was developed by M.J. Whitehouse and S.A. Lacey for inclusion in the Australian Standard for Potting Mixes (Standards Australia, 1989).

There do not appear to be any published reports of evaluations of the longevity of wetting agents under typical nursery conditions. This paper presents a rapid method for assessing longevity and two methods for evaluating a new wetting agent.

METHODS AND RESULTS

Experiment 1: Long-Term Effectiveness in Pots. Long-term effectiveness in pots was assessed with a bark/peat/sand (7 : 2 : 1, by volume) mix of known poor wettability. It was amended with wetting agents at 0.1, 0.2, 0.4, 0.8, and 1.2 ml concentrate per liter of mix. After moistening to the water content commonly found in bagged potting mix, part of the mix of each treatment was filled into 140-mm standard pots. There were four pots of each treatment housed on mesh-topped benches in a glasshouse. One *Petunia* 'Plum Tart' plug was transplanted into each pot. They were fed weekly with a nutrient solution containing all major nutrients, with N at 250 mg/liter.

At 21 weeks and 8 months after adding the wetting agents, the rewettability of the mix in the pots was assessed as follows.

The pots were dunked for 10 min and returned to the mesh-topped bench to drain. Each pot was weighed (giving "dunked weight" = container capacity) and then returned to the bench. The potting mix in the pots was allowed to dry until the plants were totally wilted. The pots were again weighed ("dry weight"), returned to the bench, and 500 ml water slowly poured onto each pot. On completion of drainage, the pots were again weighed ("wet weight"). The water retained by the mix after pour-on, relative to that in the mix following dunking [(wet weight - dry weight)/(dunked weight - dry weight)], is a measure of the effectiveness of the wetting agent in the mix.

The results (Table 1) show considerable differences between the wetting agents, with only two giving significantly better wetting than control at 8 months.

Table 1. Water retained by potting mixes treated with wetting agents following pouring water onto dry mix in pots, as a proportion of the amount retained following dunking. Data were obtained after 21 weeks in pots planted with *Petunia* 'Plum Tart'.

Wetting agent	Concentration of wetting agent in the mix before drying (ml/l mix) 0.1	0.2	0.4	0.8	1.2
	21 weeks after planting				
Aquasoil Wetter	0.32 c	0.39 c	0.53 b	0.61 a	0.68 a
Wetta Soil	0.38 c	0.44 bc	0.50 b	0.61 a	0.68 a
Hydraflo Liquid	—	0.21 d	0.21 d	0.40 c	0.52 b
Hydraflo 15G[1]	0.28 cd	0.39 c	0.45 bc	0.60 a	0.67 a
Soil Wetter	—	0.25 d	0.25 d	0.40 c	0.51 b
Agral 600	0.22 d	0.25 d	0.35 c	0.43 bc	—
Control	0.18 d				
	8 months after planting[2]				
Aquasoil Wetter	0.21 d	0.25 cd	0.33 c	0.65 a	0.67 a
Wetta Soil	0.19 d	0.21 cd	0.31 c	0.46 b	0.53 b
Control	0.14 e				

[1] Added on the basis of the solid containing 15% wetting agent.
[2] Treatments other than those listed were not significantly different from control. Numbers followed by the same letter are not significantly different with a probability of 95%.

Sources of wetting agents evaluated: Agral 600: ICI Melbourne, Vic.; Aquasoil Wetter: Chemtech Industries, Canning Vale, Western Australia; Betta Wetta: Chemspray, Sydney, NSW; Hydraflo: Sierra Australia, Castle Hill, NSW; Multicrop Soil Wetter: Multicrop, Bayswater Vic.; Soil Wetter: Nu Erth, Meadows, South Australia; Wetta Soil: Wetta Chem Products, Bunbury, Western Australia.

Experiment 2: Effects of Long-Term Moist Storage. The other part of the media used in Expt. 1 was filled into plastic bags, which were stored in a glasshouse.

The wettability of the mixes was assessed by the Australian Standard technique within a week of wetting agent addition and again at 21 weeks and 8 months.

Moist mix was filled in quadruplicate into plastic dishes, each holding 100 ml of mix. The dishes of mix were dried to constant weight at 40°C. Identical hollows were pressed into the surface of mix in each dish using a 60 watt light globe. Ten ml of

deionized water was poured into each hollow and the time in seconds taken for it to soak in was recorded.

The wetting agents generally improved the initial wettability of the mix (Fig. 1a), but there was a wide range of effectiveness. The results of assessments at 21 weeks and 8 months (Fig. 1b and Table 2) show broadly similar trends to those found in Expt. 1 indicating that this technique gives a valid assessment of what happens in containers.

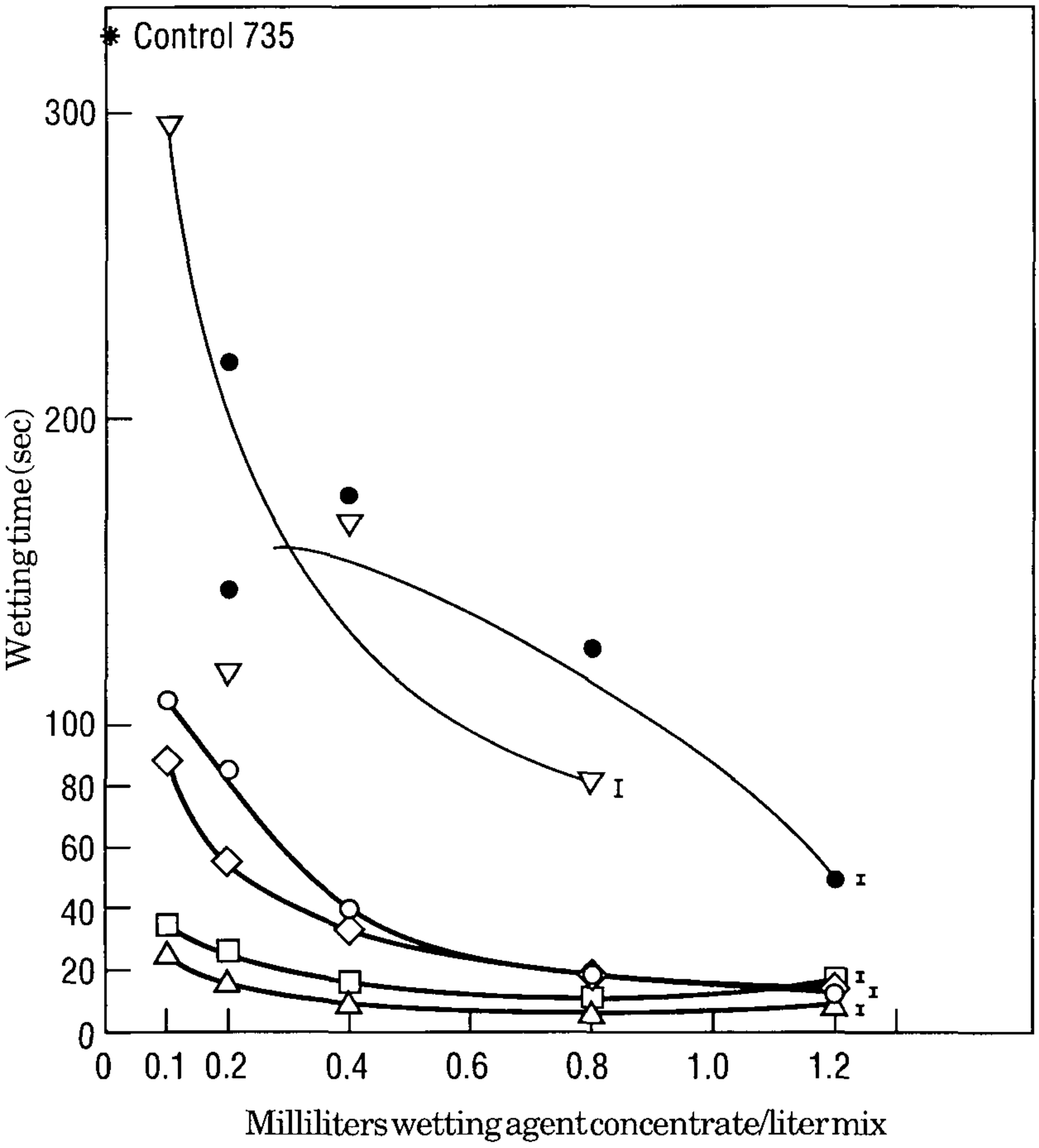

Figure 1a. Wetting time of a potting mix to which had been added 5 wetting agents. Soon after addition. The bars represent standard errors of the means for all points on a curve. □ Aquasoil Wetter; △ Wetta Soil; ▽ Agral; ◇ Hydraflo Liquid; ● Soil Wetter; ○ Hydraflo 15G.

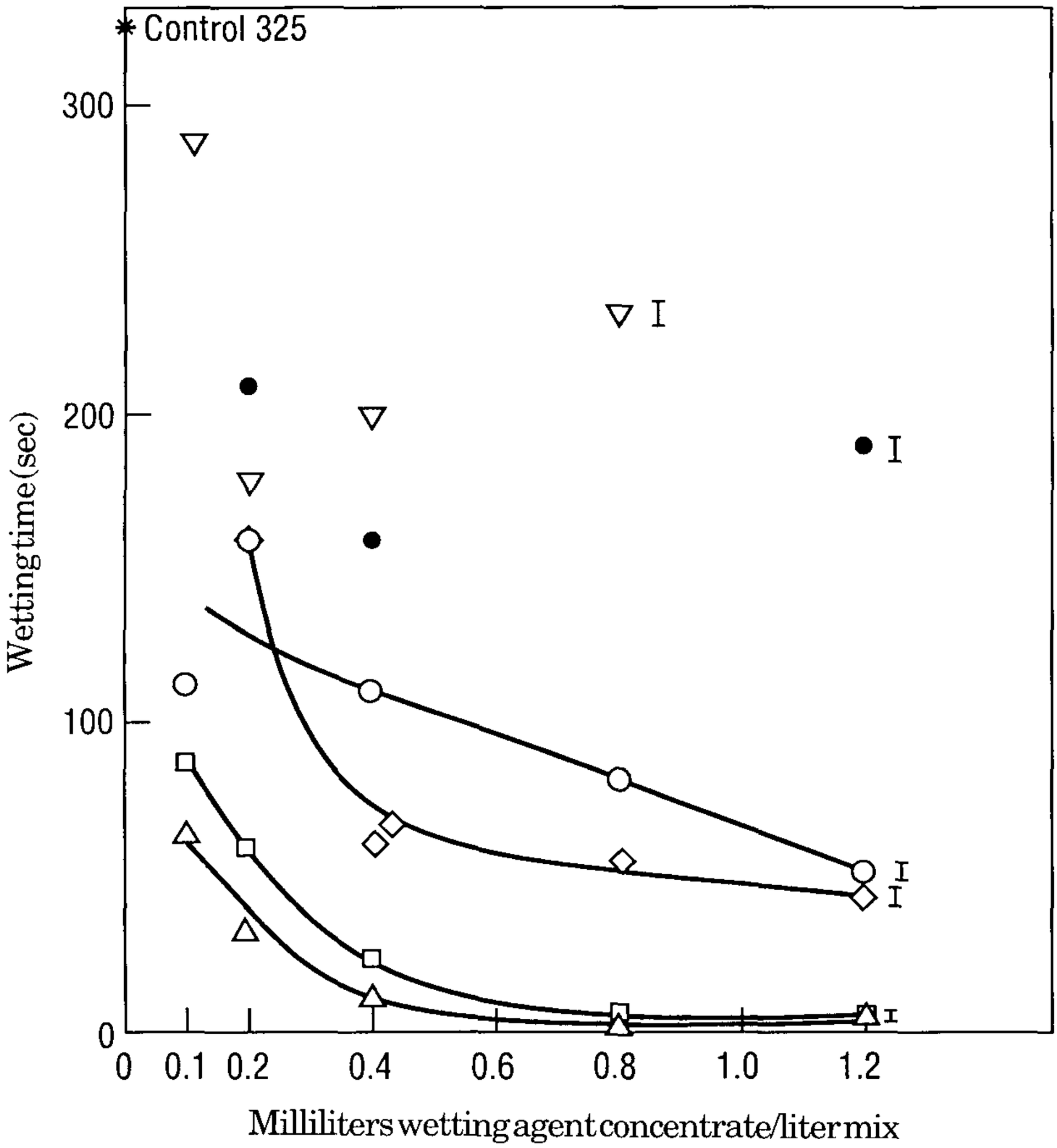

Figure 1b. Wetting time of a potting mix to which had been added 5 wetting agents. After 21 weeks of incubation. The bars represent standard errors of the means for all points on a curve. □ Aquasoil Wetter; △ Wetta Soil; ▽ Agral; ◇ Hydraflo Liquid; ● Soil Wetter; ○ Hydraflo 15G.

Table 2. Standard wettability (seconds) of potting mixes containing wetting agents, after storage moist in bags for 8 months[1].

	Wetting agent addition rate (ml/l mix)				
Wetting agent	0.1	0.2	0.4	0.8	1.2
Aquasoil Wetter	174 a	145 b	55 d	45 de	33 e
Wetta Soil	180 a	158 b	104 c	54 d	55 d
Control	197 a				

[1] Wetting times for mix samples containing Soil Wetter, Agral 600, Hydraflo Liquid and Hydraflo 15G were not significantly different from that for control mix.

Experiment 3: Evaluation by Pouring Dilute Solutions onto Dry Mix in Pots. The potting mix used for this experiment was that used for Expt. 1 and 2, but recycled after use in assessing dishwashing detergents, which were found to completely biodegrade within 14 days. The mix was dried to constant weight at 40°C. Samples, each of 325 ml, were filled into 100- mm squat nursery pots. The pots were placed on a greenhouse bench with a mesh top.

Onto the surface of the mix in each pot was slowly poured 300 ml of either deionized water (control) or solutions containing 1, 1.5, 2, or 3 ml of wetting agent concentrate per liter of solution. There were four pots of each treatment. The pots were allowed to drain for 30 min and then weighed.

All wetting agents increased the amount of water retained in the mix (Fig. 2). Retention generally increased with increases in the concentration of wetting agent in the water. There were marked differences between wetting agents, with the best allowing three times the retention of water given by the worst. The general ranking in effectiveness was similar to that found in Expt. 1 and 2.

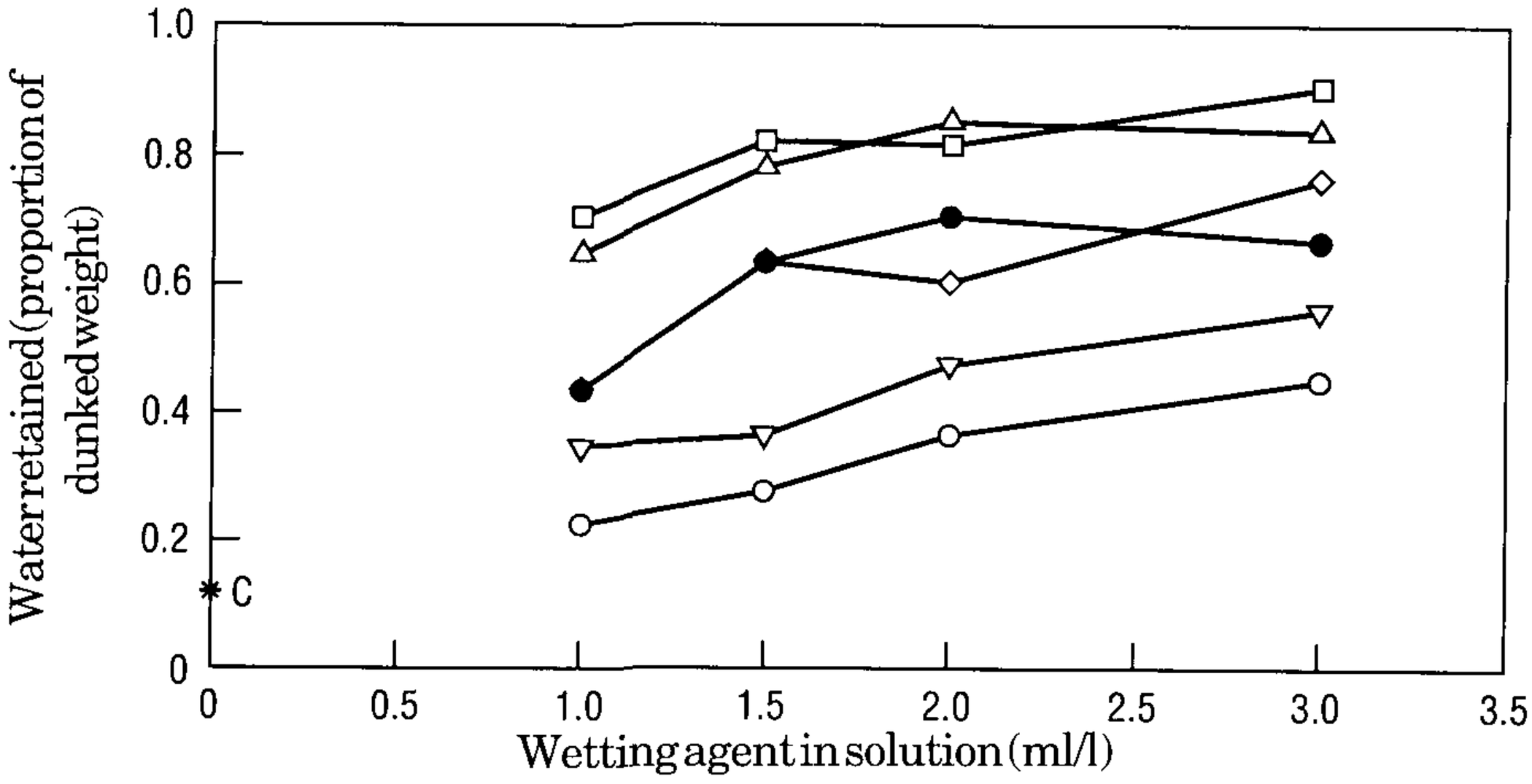

Figure 2. Retention of wetting agent solution poured onto the surface of dry potting mix, as a proportion of retention of water following dunking in water and draining. The bars represent standard errors of the means for all points on a curve. □ Aquasoil Wetter; △ Wetta Soil; ▽ Agral; ◇ Hydraflo Liquid; ● Soil Wetter; ○ Trix; C = control.

Some of the pots of mix were kept moist for 3 weeks, then dried to constant weight at 40°C and returned to the greenhouse bench. Deionized water (300 ml) was slowly poured onto each pot. They were weighed after 30 min drainage. The results are presented in Fig. 3.

All mixes containing wetting agents other than Trix dishwashing liquid were wetter at the end of drainage than was the control mix. The mixes containing Aquasoil Wetter and Wetta Soil retained considerably more water than did all other mixes.

Experiment 4: Change in Effectiveness During Short-Term Incubation. The same mix as was used in Expt. 3 was amended with wetting agents at 0.6 ml concentrate per liter. After thorough mixing, part of the mix of each treatment was immediately removed for evaluation of its wettability by the procedure of the

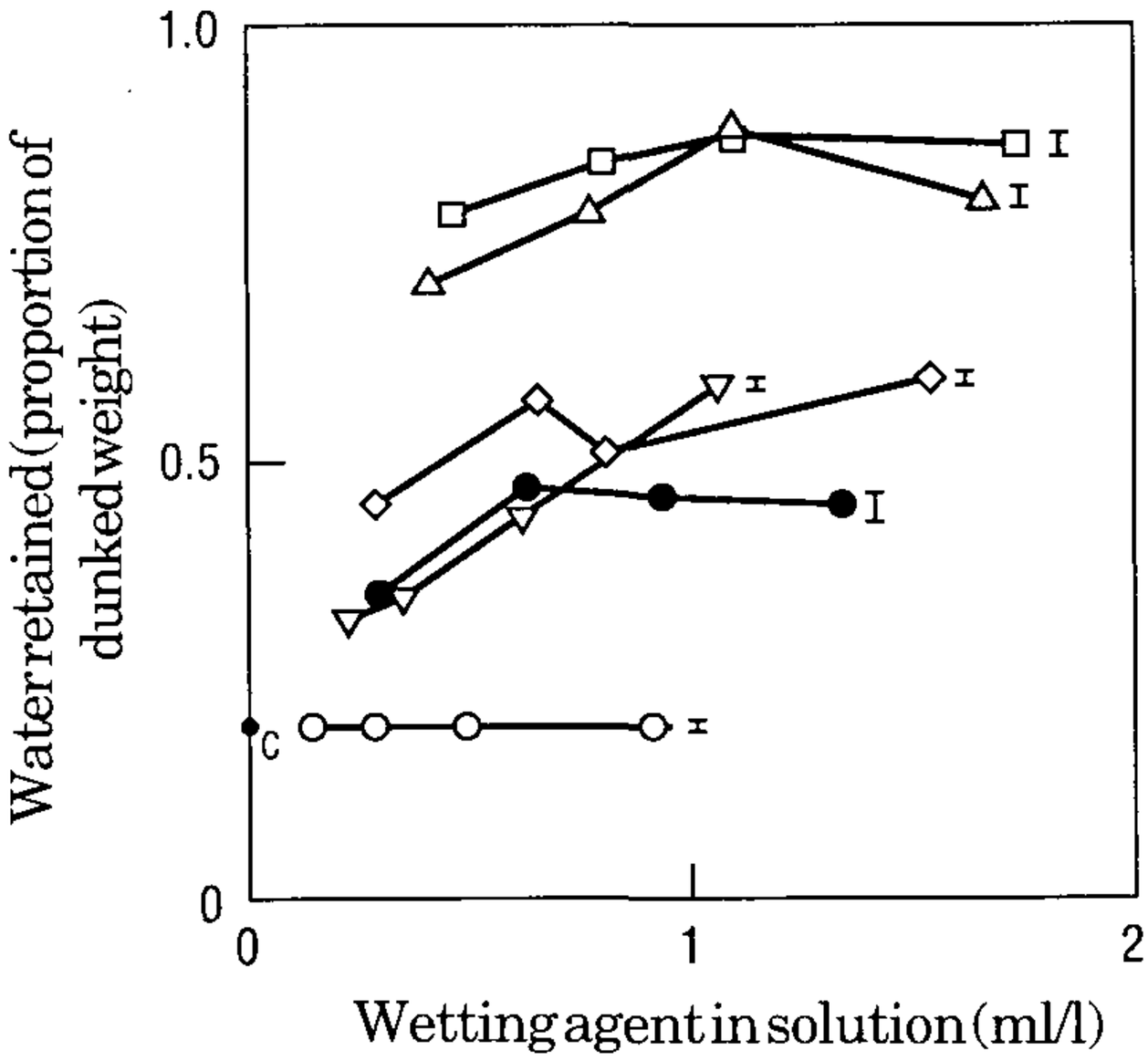

Figure 3. Retention of water poured onto the surface of dry potting mix containing various wetting agents, as a proportion of retention following dunking in water and draining. The bars represent standard errors of the means for all points on a curve. □ Aquasoil Wetter; △ Wetta Soil; ▽ Agral; ◇ Hydraflo Liquid; ● Soil Wetter; ○ Trix; C = control.

Australian Standard. The results (Table 3, first column of data) show that all wetting agents improved wettability relative to the control mix. The ranking of the wetting agents was similar to that obtained with the pour-on technique (Figs. 2 and 3).

Table 3. Effect of incubation time on the wettability of a potting mix to which had been added various wetting agents at 0.6 ml concentrate per liter of mix. Wettability figures are in seconds needed to wet the mix under standard conditions.

	Days of incubation				
Treatment	0	4	8	16	30
Wetta Soil	3 de	3 de	3 de	6 bcd	14 b
Aquasoil Wetter	5 bcd	4 cde	4 cde	6 bcd	16 b
Hydraflo 15G[1]	7 bcd	5.5 bcd	7.5 bcd	12 bc	28 ab
Multicrop Soil Wetter	8 bc	8 bc	8 bc	24 ab	31 ab
Hydraflo Liquid	10 bc	10 bc	16 b	26 ab	36 a
Agral 600	10 bc	11 bc	16 b	29 ab	45 a
Soil Wetter	12 bc	15 b	20 ab	42 a	64 a
Betta Wetta	12 bc	18 b	22 ab	49 a	57 a
Control	50 a	62 a	55 a	52 a	59 a

[1] Added on the basis of the solid containing 15% wetting agent. Numbers followed by the same letter are not significantly different with a probability of 95%.

The mixes were incubated at 25°C in plastic bags for 30 days. Samples were removed at 4, 8, 16, and 30 days for re-evaluation. The results (Table 3) show that there was a gradual to rapid decline in the effectiveness of the wetting agents. Those that were the least effective initially were also the first to lose effectiveness.

CONCLUSION

All test methods gave similar rankings of the wetting agents. The results indicate that mixes for short-term crops such as bedding plants will wet satisfactorily with 0.1 ml concentrate per liter mix. A new wetting agent can be rapidly compared with an existing one of known effectiveness using the pour-on technique and a 20-day incubation followed by assessment with the Australian Standard technique.

AN ALTERNATIVE TO THE AUSTRALIAN STANDARD METHOD

Assessment of the Short-Term Effectiveness of a New Wetting Agent. Dry some potting mix known to have poor rewettability. Fill it into standard or squat 100 mm nursery pots. The volume of mix in each pot must be the same. Allow at least four pots for control (water) and for each wetting agent being tested. Prepare solutions of the new wetting agent and one of Aquasoil Wetter or Wetta Soil. Each solution is to contain 1 ml concentrate per liter of solution. Slowly pour onto a pot a volume of solution equal to the volume of dry mix in the pot. Use water for the control pots. Allow drainage to finish; weigh each pot. The greater the amount of solution retained, the better the short-term effectiveness of the wetting agent.

Method for Estimating the Longevity of a Wetting Agent. Obtain enough mix known to have poor wettability to give 2 liters for each treatment. That means a minimum of 6 liters (2 liters for each of: control = no wetting agent; unknown wetting agent at 0.6 ml/liter mix; an excellent wetting agent (e.g. Aquasoil Wetter or Wetta Soil at exactly the same rate). Measure 2 liters of mix into each of three plastic bags.

Make up a dilute solution of each wetting agent containing 12 ml concentrate per liter of solution. Add 100 ml of this to 2 liters of mix. Add more water as needed to make the mix a little wetter than it would normally be for potting. Add plain water to the control mix. Make each plastic bag to the same weight. Thoroughly shake the mix and immediately remove about 600 ml. Store this in a plastic bag in a refrigerator.

Store the bags of incubating mix in a situation where the temperature will be reasonably constant, preferably in the range 20 to 25°C. Remove further 600 ml samples at 20 days.

From each 600-ml sample fill four plastic dishes, each holding about 100 ml. Disposable plastic dishes measuring about 75×75×22 mm are ideal. Proceed as described above in Expt. 1.

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Water Quality in Propagation

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INTRODUCTION

Over 70% of the world's surface is covered by water, but 97% of this water is salty. Of the remaining 3% of fresh water, 2/3 is tied up in glacial ice. Only about 7/8 of 1% of the world's freshwater is liquid, and 95% of that is underground. In most countries 90% of people depend on ground water as drinking water. Looking at these figures it is clear why our ground water resources are so precious.

To many of us water is taken for granted. Most of us have water on tap in our homes to use for drinking and washing, and watering our gardens. When we take a glass of water to drink, and we look into it and through it, how many of us realise the effort that has gone into making that water safe for us to drink. It has been taken from a storage facility, many kilometres away, and after many treatments and tests, it is delivered to our home. We take for granted that all has been done to it that is necessary, to make it safe for our use.

I am sure that our thoughts of safety in water supplies carry over in many cases to the water we use on our nursery crops. We look at water as essential to plant growth, which of course it is. What many do not consider is that it can also be the carrier of a deadly brew of bacteria and fungal spores just ready to explode into growth when applied to propagation and growing areas and to the media in which plants grow.

This paper is designed to make you think about what you are doing. All the best hygiene in the world will break down, if you do not get this essential area right.

In propagation of plant material, whether by seed or cutting, all of us realise that water, in its basic form, is one of the most critical elements for success. I would suggest that all of us think long and hard about the media type we use, about the fertilisers we incorporate, and about the types of cuttings or seed material we use, but I am sure very few give much thought to the unwanted microorganisms in the water we apply. Through its physical properties water can dissolve, hold in suspension, and spread many things that are harmful to our crops.

Over the years, many ways have been introduced to maintain moisture in the seed or cutting until it germinated or rooted. Only once the seed or cutting has established itself does this reliance on moisture become less critical. At this stage of its development we wean the young plantlet to normal cultural practices.

PLANT PATHOGENS IN PROPAGATION WATER

In applying water to hold transpiration to a minimum we use several methods. All of these methods result in water from an outside source being applied in lesser or larger quantities to our propagation benches.

Plant pathogens can be transferred in surface water. They are commonly called water moulds, and include *Phytophthora*, *Pythium,* and *Rhizoctonia*.

On cutting benches and in seedling trays, *Phythium* and *Rhizoctonia* are devastating. *Phytophthora* fungi are generally slower-working, but always results in the eventual death of the plant. It is critical, at all stages of the nursery program,

that we use water from a clean source, or that we treat the raw water to ensure that it is completely free of pathogens.

In most cases water coming from deep wells is clean. However, tests for pathogens would need to be carried out over a long period to ensure that the source is clean. One must not take it for granted that because one is using well or bore water, one will have no problems. These tests for problem pathogens must be carried out throughout the year, including very wet and very dry periods of the weather cycle, and should continue for at least two full cycles of the seasons.

DESTROYING UNWANTED PATHOGENS

There are several ways of treating water to kill these unwanted microorganisms.

Filtering—The First Step. In using any method, water has to be filtered beforehand to remove suspended silt and solids. Sand filters are commonly used for this purpose. Impurities in the water tie up chemicals being applied and result in a situation that is impossible to monitor. Sand filters are back-washable, and can either be hand-operated or automatically operated, depending on the amount of sediment to be filtered from the raw water.

Chemical Water Treatments. Available water treatments to eliminate pathogens are of two types. These are by chemical treatment or physically by micron filters or ultraviolet light. Chemical treatments in use include the following:

Chlorination.

- Chlorination by injection of chlorine gas.
- Chlorination by injection of liquid sodium hypochloride.
- Chlorination by batching water and adding calcium hypochloride powder.

Bromination. The systems I have seen in use in nurseries were using sodium bromide in a solid form. These blocks were immersed in the storage tanks. Water was used for irrigation after predetermined times from the storage filling.

Ozone. One reads of this treatment in the literature. I have not seen it used in our industry, but did hear a paper on it at a conference which told us that ozone is extremely corrosive and also highly toxic. I doubt that it is of use in our industry.

NON-CHEMICAL TREATMENTS.

Fine Membranes. Fine membrane filters could be used but in practice, the sheer volumes of water often needed, will mean that the installation will have to be so large as to be uneconomical.

Ultraviolet Light Irridation. This system works well if water going into the treatment area is clear. Silt particles, and even minor impurities in the water, will result in some escape areas for pathogens. Silt particles can shield some of the water passing through from the light, just as a door will either let light shine through or be dark, depending on whether it is shut or open. Impurities can discolour the tubes the lights are in, so maintenance of this area is on-going.

WATER TREATMENT AT REDLANDS GREENHOUSES

It is not up to me to recommend one treatment above any other. Each has its place and it depends on each operator to choose the one best suited to the operation.

In our situation, where we reuse water from holding ponds, we catch our excess through a system of drains and paths that run through the growing areas of the nursery sites. This water is relatively clean, and so we manually backwash our filter on a two-day rotational basis. After heavy rain, when our creeks run and dams fill, we switch to daily washing until the excess sediment in this run-off water settles.

These filters are relatively trouble free. We clean them on a regular basis, and recharge the sand whenever necessary.

Water is pumped from the dam, through the filter, into holding tanks, where we add liquid sodium hypochlorite. We endeavour to make sure that the treatment has at least 30 min to work in the tank before we use the water. The cleanliness of water for propagation purposes is more critical than general irrigation water for growing fields. In all cases pathogens must be eliminated.

We aim for 4 ppm of residual chlorine at discharge. We test for this residual with a pool chlorine test kit, and use our eye for colour comparison with the chart enclosed with the kit. We have found this successful.

Water which has dissolved quantities of fertiliser salts even in small amounts, is not always suitable for propagation purposes. I can recall one instance, several years ago, when we used our usual irrigation water for our mist benches. We lost many of our native plant cuttings through the small amounts of dissolved fertiliser salts in the water. It was a disaster. We changed back to town water supply, and immediately the problem went away.

Therefore, if one has to use recycled water for propagation benches, I would strongly suggest blending with a better source of water, if at all possible. In this way you can dilute the residual fertiliser salts to a more tolerable level. This can be monitored simply with a small EC meter.

WATER APPLICATION AND HYGIENE IN APPLYING WATER

Water application to propagation beds and to crops is an area of variability. Each employee has a slightly different appreciation of what is enough, and what is too much. It is very hard, if not impossible, to teach the art of watering to most employees. There is a relatively fine line between a flood and a drought. The water needs of plants vary tremendously and nowhere is this more apparent than in the propagation department. When one has a mixture of unrooted cuttings, just-rooting cuttings, and rooted plants at many stages of development awaiting potting up, we have created a nightmare in so far as watering is concerned.

Quality can so easily be sacrificed at this stage. If you opt to use overhead automatic watering, you will find that some plants get too much water and others too little. With this situation, hand-watering for at least part of the week is needed. Otherwise edges of benches and trays get too dry while centres get too wet. In cooler months of the year, watering by hand is essential for best quality.

Mist and fog nozzles are also an area where quality of watering can be sacrificed. Cleanliness of the system should result in few blockages, but vigilance and a cleaning of the nozzles is necessary on a regular basis.

Some things are so obvious but simply overlooked. It is common to visit nurseries and see hoses lying on the ground with the nozzles lying on the ground, either on

the bed or the track. A simple wire hook at the tap is all that one needs to keep the nozzle off the ground and out of the way. A sure way of picking up water-borne pathogens from the ground is thus eliminated.

We have done all we can to treat our water. The system is only as good as the operators. All will fall down unless the propagation area is kept "kitchen clean." Hygiene is one of the tools of the propagator that is sometimes neglected. A lot of problems can be eliminated with just a little more attention to detail in our work area and surrounds.

I don't know the explanation, but I am told that algal bloom in rivers and water storages results in a lowering of oxygen in the water and in severe cases this causes dead water. Whilst visiting the Southern Region I.P.P.S. meetings last year in Maryland and Virginia, we saw nurseries that were doing things to correct this problem with reused water.

The water in the holding dams, where the run-off was caught, had large fountains playing in them. This resulted in any floating debris being pushed to the side of the dam where it was skimmed off. The water was collecting oxygen from the air as it was lifted and sprayed through the fountain. The dams were very clean. In speaking with the propagators at these nurseries we were told that they were having much better results in their propagation houses since this water treatment was started. They put this down to extra oxygen in the water being applied. I wonder what would result if we super-charged water with as much oxygen as it would absorb? Here, no doubt, is an area for research.

In 1972, the U.S. Congress amended the Federal Water Pollution Control Act, so that the EPA delegated to Regional Boards the responsibility of setting water standards in their areas.

One of the guidelines sets a limit of 45 ppm nitrate (10 ppm N) for discharge water. This is the current drinking water standard. Most nurseries using ammonium nitrate in constant liquid feed, use 200 ppm N, so would have 20 times the allowable figure. Other residual limits per liter are:

- 75 mg suspended solids
- 15 mg oil and grease
- 750 mg total dissolved solids
- 175 mg chloride
- 500 mg sulphate

There is no way anyone can meet these standards unless discharged water is treated. In addition, one cannot discharge without a permit, and this requires inspection. Some states have tight controls in place; most others have a deadline of 1993 for compliance. Nurseries in Texas have to collect all run-off for reuse, and also they have to collect the first 1/2 in. of rainfall each time rain falls. Fines for infringements are **$10,000 per day** until fixed.

I would leave you with the thought that we should put a lot more thought into the way we use water in our propagation and growing systems. It is a precious resource, and is one that is becoming limited on a global scale. We have to find ways to use less water, and to re-use the water that we usually let run away.

We will have to come to terms with reusing this run-off. If we don't do it voluntarily, we will be forced by legislation. How much better it is to be prepared, and get our nurseries in order before this happens.

A Review of Materials for Propagation Media

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INTRODUCTION

The aim in plant propagation is to produce healthy, well-grown plants, with minimum losses, in the shortest possible time. We must bear in mind that the propagation stage is the most vulnerable growth stage in nursery production and any adverse factors which affect the number and quality of plants being propagated is felt all the way down the nursery production line. This paper reviews the materials which are used in plant propagation media and attempts to determine how propagation management practices may influence propagation success.

FACTORS OF IMPORTANCE IN THE SELECTION OF INGREDIENTS FOR PROPAGATION MEDIA—A REVIEW

1) Hygiene Status. Media materials must be free of all pests, diseases and weeds. Some materials, such as vermiculite, perlite, and rockwool, are processed at very high temperatures and there should be no requirement for hygiene treatments, provided they are stored in hygienic conditions in the nursery.

Other materials, such as peat, bark, and sawdust will not necessarily be free from pathogens and some hygiene treatment may be necessary. This also may be determined by the way in which these materials are stored on the nursery.

During propagation, pathogens that cause damping-off diseases will spread very rapidly due to the highly favorable conditions provided in the propagation environment and if you know that a particular ingredient is contaminated, it should either be treated or replaced.

2) Available Air. The amount of air contained in propagation mixes is very important as watering is frequent during propagation and there is a constant danger of waterlogging, especially if mist propagation is used.

The amount of air in a mix is expressed as the "air-filled porosity" (AFP) of the mix, which is the percentage of the total volume of the container that is air space. In normal potting mixes the desired air-filled porosity is in the range of 15% to 20%, but for propagation mixes it is desirable to build in more air. The greater the possible risk of waterlogging of propagation media, the higher the air-filled porosity should be. AFPs of 25% to 40% are not uncommon for propagation mixes.

It should be borne in mind that as the proportion of air in a mix increases, the amount of available water decreases and mixes with a high AFP must be watered frequently. Ingredients with a large particle size will have a higher AFP than ingredients which are very fine. Therefore it is important to avoid the use of materials which have a high proportion of very fine particles. The type of mixer and the duration of mixing can have an effect on the particle size, and therefore the AFP. Avoid mixing for any longer than is absolutely necessary to achieve a uniform blend.

3) Available Water. The amount of water available within a propagation mix will determine the frequency of watering required with the mix. It is probably fair to say that in propagation over watering is a more common problem than under watering and we should take great care to avoid watering containers unless it is clear that the medium requires water. Most nurseries have the capacity to water propagation containers on a regular schedule so in the design of propagation mixes it is more important to concentrate on building in a sufficiently high air-filled porosity than a very high water-holding capacity.

4) The Presence of Toxic Substances. Wood waste products such as hardwood sawdust and pine bark may contain toxic substances such as phenol compounds. In general potting mixes these compounds may cause few or no problems, but young plants at the propagation stage are likely to be vulnerable to even small quantities of wood-based toxins. Both bark and sawdust are being successfully used in some nurseries as alternatives for expensive imported peat in propagation mixes, but adequate composting must be carried out and the materials heavily leached to wash out these toxic substances.

5) The Problem of Nitrogen Drawdown. Wood-based products have the additional problem that nitrogen may be temporarily depleted as a result of bacterial decomposition of the particles, which requires the presence of nitrogen. There is a danger that the small quantities of nitrogen added to the mix to cater for the initial growth of the plants being propagated will be utilized by the bacteria in this process of decomposition and there is no nitrogen available for plant growth. The use of slow-release nitrogen sources in mixes which contain large amounts of organic matter will minimize this problem.

6) Other Factors. The nursery producer will take a number of other factors into consideration in the formulation of a suitable propagation medium. These factors include:

- Correct pH
- Soluble salt levels
- Consistency of quality
- Ease of mixing
- Weight of the finished mix
- Simplicity of the mix formula
- Cost of the mix

However, these other factors are outside the scope of this paper and will not be considered further.

MATERIALS AND METHODS

Samples of ten different formulations of propagation media were prepared in the Plant Nursery Unit at the University of Queensland, Gatton College and the air-filled porosity of each mix was determined.

Propagation Media Used

T1 Peat : Sand (ungraded) 50 : 50

This mix was formulated using New Zealand peat and a very coarse grade of sand which is widely used in the local nursery industry.

T2 Peat : Sand (graded) 50 : 50

This formulation contained the same New Zealand peat (as T1) but the sand was subjected to a grading process to remove the excessively large and small particles (<1 >2 mm).

T3 Peat : Vermiculite 50 : 50

This medium is widely used in the Lockyer Valley nursery industry for the production of cell-grown vegetable transplants. New Zealand peat was again used and the vermiculite used was grade 3.

T4 Peat : Vermiculite : Perlite 1 : 1 : 1

This is the standard cutting propagation mix used at Gatton College and consists of New Zealand peat, grade 3 vermiculite, and P500 perlite.

T5 Peat : Perlite 50 : 50 (ungraded)

This mix consisted of New Zealand peat and P500 perlite. The perlite which is available in Queensland has a very wide range of particle sizes from very small to coarse. This mix had no grading carried out.

Table 1. The air-filled porosity of the propagation media treatments

Treatment number	Description of treatment	Air-filled porosity (%)
T1	Peat : Sand	21.6
T2	Peat : Sand (graded)	17.5
T3	Peat : Vermiculite	35.0
T4	Peat : Vermiculite : Perlite	48.3
T5	Peat : Perlite	42.5
T6	Peat : Perlite (graded)	48.3
T7	Bark : Sand	19.1
T8	Sawdust : Sand	30.0
T9	Bark : Sawdust : Sand	17.5
T10	Bark :Peat	27.5

T6 Peat : Perlite (graded) 50 : 50

This mix had the P500 perlite graded by passing though a 1-mm screen to remove all fine particles. It had been suggested that grading of Australian perlite would improve the AFP which would in turn improve cutting performance in this mix.

T7 Bark : Sand 50 : 50

The bark used was composted slash pine (*Pinus elliottii*) bark with a coarse particle size for general potting. The sand used was ungraded coarse sand.

T8 Sawdust : Sand 50 : 50

The sawdust used was naturally weathered hardwood sawdust which had been allowed to weather on an outdoor concrete slab for over 2 years. The sand used was ungraded coarse sand.

T9 Bark : Sawdust : Sand 1 : 1 : 1

This mix consisted of equal parts of the three materials already described.

T10 Bark : Peat 50 : 50

This mix was included as a result of the author's observations of the hardy ornamental nursery stock industry in England. Very finely granulated Irish peat has caused problems in the English nursery industry and some growers add composted pine bark to the peat to improve the air-filled porosity.

The air-filled porosity of each mix was measured and the readings achieved are shown in Table 1.

Cuttings of two species of ornamental plants were propagated in each of these propagation mixes to determine the most successful combination of ingredients. The plant species used were:

- *Nandina domestica* 'Nana', the dwarf sacred bamboo
- *Callistemon* 'Kings Park Special', red flowered bottlebrush

Propagation Environment. The environment used was a shaded fiberglass propagation greenhouse with a high pressure fogging system set to maintain 90% relative humidity and a warm-water bench heating system set at 25°C. The media in the propagation containers was watered by hand throughout the trial as required.

Table 2. Rooting percentage and root quality in the propagation of *Nandina domestica* 'Nana' stem cuttings.

Treatment number	Description of treatment	Rooting (%)	Root quality	Air-filled porosity (%)
T1	Peat : Sand	100	3.75	21.6
T2	Peat : Sand (graded)	100	3.58	17.5
T3	Peat : Vermiculite	100	3.75	35.0
T4	Peat : Vermiculite : Perlite	100	3.83	48.3
T5	Peat : Perlite	100	3.50	42.5
T6	Peat : Perlite (graded)	100	3.41	48.3
T7	Bark : Sand	83	2.50	19.1
T8	Sawdust : Sand	100	2.75	30.0
T9	Bark : Sawdust : Sand	83	3.58	17.5
T10	Bark : Peat	100	3.75	27.5

Propagation Container. Standard plastic seedling punnets were used with 8 cuttings per punnet. Three replications of each treatment were used.

Auxin Treatments. All cuttings were given a 10-sec dip in a 4000 mg/litre IBA liquid dip.

Fertilizer Treatment. All media treatments had the equivalent of 1 kg/m^3 mini Osmocote® incorporated during the mixing process.

RESULTS AND DISCUSSION

Two criteria, percentage rooting and rooting quality were used to determine the effectiveness of each media.

Percentage Rooting. This is a straight rooting percentage averaged over the three replicates of each treatment.

Root Quality. Root quality was obtained through the use of a 1 to 5 qualitative scale with 1 being the lowest and 5 being the highest quality rating.

Table 2 shows that with only two exceptions all treatments achieved 100 % rooting. This obviously suggests that dwarf nandina is a relatively easy plant to strike from cuttings. However, root quality varied considerably with treatments 3, 4, and 10 showing a somewhat better quality of root development.

There was a considerable degree of variability within replicates of the same treatment with dwarf nandina and this may suggest that there was variability within the cutting material selected.

The trial with dwarf nandina did not show any direct correlation with root development and air-filled porosity of the propagation mix.

Table 3. Rooting percentage and root quality in the propagation of *Callistemon* 'Kings Park Special' stem cuttings.

Treatment number	Description of treatment	Rooting (%)	Root quality	Air-filled porosity (%)
T1	Peat : Sand	58.0	3.14	21.6
T2	Peat : Sand (graded)	54.1	3.54	17.5
T3	Peat : Vermiculite	79.1	4.08	35.0
T4	Peat : Vermiculite : Perlite	79.1	4.12	48.3
T5	Peat : Perlite	56.2	3.37	42.5
T6	Peat : Perlite (graded)	54.1	3.50	48.3
T7	Bark : Sand	45.8	2.79	19.1
T8	Sawdust : Sand	4.16	2.00	30.0
T9	Bark : Sawdust : Sand	8.30	1.87	17.5
T10	Bark : Peat	95.8	4.54	27.5

In the propagation of *Callistemon*, treatment 10 was considerably better than all other treatments — both in percentage rooting and in root quality. A visual inspection of all treatments prior to final sampling confirmed this as all replicates

of treatment 10 stood out clearly. The cuttings were a much darker green colour, bud development was much further advanced than all other treatments, and the root development was much better with a greater number of roots emerging from the stems.

The treatments with vermiculite were also substantially better than other treatments, both in percentage rooting and in root quality.

In the propagation of *Callistemon*, treatments containing hardwood sawdust performed very badly and this may be due to the effect of toxic phenols which can suppress root development.

Again, there was no direct correlation between the root development on *Callistemon* with the air-filled porosity of the propagation media.

CONCLUSION

On the basis of the results obtained with these two plant species, it is obvious that treatment 10, the bark and peat combination, warrants further investigation.

It is clear from these trials that air-filled porosity, per se, is not the predominant factor in root development. It is more likely that air-filled porosity in combination with the watering practices used in the propagation environment determines root development.

Where misting systems are used in propagation, large amounts of free water accumulate in the propagation media, and a very high AFP is required to compensate for this. However, in the Gatton College propagation house a fogging system is used for humidity control. This maintains a humid atmosphere without putting free water into the propagation media. This means that the media dries out and requires regular watering by hand to maintain moisture levels. Under these conditions, propagation media with lower AFPs can perform as well as media with higher AFPs.

Further work will be carried out to gain a better understanding of the factors which determine propagation success with a range of different propagation media.

Coal Ash as a Propagation Medium

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INTRODUCTION

My nursery produces tube stock of various lines for sale in 2-in. (5 cm) tubes. The cutting medium that I had settled on before trying ash consisted of 3 parts washed river sand, 2 parts peatmoss and 1 part perlite (SPP).

As propagators, we are always trying to find ways of improving our techniques so as to obtain better results. During conversations with various propagators I became aware of the use of coal ash as a striking medium. Some of the results that these people were quoting suggested to me that some trials might prove worthwhile.

I decided to try it out by putting a very small percentage of my normal production into coal ash medium. These initial trials proved promising so in the following season I increased the percentage of cuttings in coal ash. To ensure a workable comparison, I put my programmed cutting production into the two media on an approximately 50/50 basis. Production proceeded as it normally would. No changes were made to hormone use, bottom heating, or misting settings. Accurate records of the results were kept. Some of these results are listed below (See Tables 1, 2, 3, and 4 for comparisons between coal ash and a sand, peatmoss and perlite medium).

COAL ASH

What Exactly is Coal Ash? It is the ash which is left after black coal is burnt in an industrial boiler or furnace. In other words, it is a waste product. The raw coal is crushed and graded to a small particle size (approximately 1/4 in. or 6 mm.). After burning, the ash is then removed from the boiler and cooled by spraying with water. In some cases, salt water is used to cool the ash. This product could not be used. The coal used in my area has a low phosphorus content.

Preparation for Use. The only preparation used to ready the ash for use in propagation is sieving. It has been found that 3/16- to 1/4-in. mesh (5 mm to 6 mm) is the best. In my nursery I sieve the ash through a 3/16-in. mesh builders sieve. Some soil suppliers will sieve ash before delivery when large quantities are to be supplied. Larger size mesh leaves particles which are too big and interfere with dibbling, particularly in small cell packs. All the material that falls through the sieve is used including the very fine particles. In my experience, when striking finer cuttings, such as *Coleonema,* sieving through a 3/16-in. sieve gives a better result.

Analysis. Some pH variation has been found from batch to batch of coal ash and some may need to be adjusted. This particular ash does not have excessive levels of anything that would harm plants. Other ashes must be analysed before use.

Storage. Some care should be taken to provide hygienic storage conditions for ash. As it is sterile when delivered, it could be prone to the rapid spread of fungal pathogens if stored on bare soil or left in the open. If storage in a clean undercover area is not available, re-sterilization may be needed.

Table 1. Examples where strike was better in ash than in standard mix.

Plant	Medium	No. cuttings planted	No. cuttings stuck	Strike rate (%)
Callistemon viminalis 'Little John'	SPP[1]	273	90	33
	ASH	273	226	83
Juniperus virginiana 'Skyrocket'	SPP	198	74	37
	ASH	396	226	57
	ASH	420	396	94
Nerium oleander "Splendens Variegatum"	SPP	40	12	30
	ASH	217	202	93
Metasequoia glyptostroboides	SPP	198	54	27
	ASH	228	144	63
Coleonema 'Rubrum'	SPP	198	6	3
	ASH	198	46	23
Rosa banksiae	SPP	198	56	28
	ASH	396	191	48

[1] SPP = sand, peatmoss, and perlite medium; ASH = coal ash.

Table 2. Examples where strike in ash was not better than in standard mix.

Plant	Medium	No. cuttings planted	No. cuttings stuck	Strike rate (%)
Pyrostegia venusta	SPP[1]	912	870	95
	ASH	131	118	90
Coleonema pulchrum 'Sunset Gold'	SPP	396	310	78
	ASH	792	454	57

[1] SPP = sand, peatmoss and perlite medium; ASH = coal ash.

Cost. Sand, perlite, and most particularly peatmoss are quite expensive in Australia. I also find that the sand available today is generally very dirty and much time is spent washing it prior to use. Taking this into account, the approximate cost of my usual cutting mix is about $160.00 per cubic metre.

Table 3. Examples where cutting struck quicker in coal ash.

Plant	Difference (SPP-ASH)[1] (days)
Buxus sempervirens 'Arborescens'	42
Rhaphiolepis umbellata	23
Camellia sasanqua	35

[1] SPP = sand, peatmoss and perlite medium; ASH = coal ash.

Table 4. Examples where no marked difference was noted.

Plant	Medium	No. cuttings planted	No. cuttings stuck	Strike rate (%)
Jasminum polyanthum	SPP[1]	192	192	100
	ASH	3042	3008	99
Nandina domestica 'Nana'	SPP	560	544	97
	ASH	1480	1434	97
Vinca minor	SPP	396	389	98
	ASH	396	396	100
Buxus microphylla 'Microphylla'	SPP	198	197	99
	ASH	792	739	93
Coleonema pulchrum 'Compactum'	SPP	546	451	82
	ASH	273	219	80
Michelia figo	SPP	198	198	100
	ASH	369	354	96
Murraya paniculata	SPP	1840	1713	93
	ASH	860	807	94

[1] SPP = sand, peatmoss and perlite medium; ASH = coal ash.

However, in Sydney, ash costs approximately $30.00 per cubic metre. The often faster striking rate of cuttings in ash produces additional cost reduction through more efficient use of heated bench space.

Watering Requirement During Use. The water-holding and drainage characteristics of coal ash have proven to be very good, with one of the test results I received going as far as to describe it as "a near perfect propagation mix, physically". It is very easy to wet and re-wet and its good drainage makes it ideal if inexperienced personnel are watering. I have found that basal rot of cuttings has been almost eliminated when using coal ash, whereas it can be prevalent in an overwatered sand, perlite, and peat mix.

It has been reported to me that coal ash can become quite dry without detrimental effects on the cuttings in it.

Although air filled porosity can be a bit low, I have found this to be a problem only in 273 cell packs—which has very small cells.

Root Structure. There is some difference in root structure in ash. Roots are more numerous, although shorter relative to those in my standard cutting mix. However, no discernible difference in growth was noted after potting-on.

CONCLUSION

In conclusion, I feel that coal ash is a rooting medium with a lot of promise and economic benefits. If a local supply can be found, my advice is "get some, have it tested, and try it out."

Commercial Application and Mass Rearing of Beneficial Insects for Integrated Pest Management

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Interest in alternative strategies for the management of insect and mite pests of commercial crops is growing rapidly. The use of mass-reared beneficial insects can be a valuable tool for the practical application of such strategies. This paper discusses some of the problems associated with the production and use of beneficial insects and offers some suggestions for the future.

INTRODUCTION

Beneficial insect and mite species are presently being mass-reared for use in IPM and biological control programmes in Australia for the control of a number of key pests in horticultural and field crops. At this stage the industry is still very small but will be under pressure to expand as the interest in alternatives to conventional pest management grows. It is important that this growth occurs in a logical and ordered way. This will only happen with cooperation between the horticulture industries, the suppliers of beneficials, and government research facilities.

INTEGRATED PEST MANAGEMENT IN CITRUS—A CASE STUDY

IPM has been practised in citrus in Queensland for 13 years now and has resulted in the reduction of pesticide use by around 80% to 90%, with no adverse effect on fruit quality (Papacek and Smith, 1992). The programme features cooperation between growers, consultants who monitor the crop on a regular basis, government researchers, and suppliers of beneficial insects. A similar programme is operating successfully in South Australia.

The development of integrated mite control strategies in glasshouse and nursery environments is paving the way for the transition to a complete integrated pest management package in the industry. Such a transition will best occur within a cooperative framework as in the citrus example.

BENEFICIAL INSECTS NOW COMMERCIALLY AVAILABLE

Four commercial insectaries presently supply the following range of predatory and parasitic arthropods in Australia.

Supplier	Species available	Target pest
Bugs for Bugs	*Aphytis lingnanensis*	California red scale
Mundubbera Q	*Leptomastix dactylopii*	mealybug (*Planococcus citri*)
	Cryptolaemus montrouzieri	mealybugs
	Chilocorus circumdatus	citrus snow scale
	Chilocorus baileyi	oriental scale
Biological Services	*Aphytis melinus*	California red scale

Supplier	Species available	Target pest
Loxton SA	*Encarsia formosa*	whiteflies
	Typhlodromus occidentalis	spider mites
BioProtection	*Phytoseiulus persimilis*	spider mites
Warwick Q		
Hawkesbury IPMS	*Phytoseiulus persimilis*	spider mites
Richmond NSW		

USE OF BENEFICIAL INSECTS IN IPM PROGRAMMES

Predatory and parasitic arthropods can be used to assist in the control of pest species in the following ways:

Inundative Release. Large numbers are released to exercise control over a pest in a short period of time, much as a conventional pesticide would be used.

Inoculative Release. Release of small to moderate numbers to:

- Supplement relatively low numbers of beneficials in the crop, or
- Re-establish populations of beneficials following adverse conditions such as harsh winters and pesticide application.

Dribble Release. Relatively small numbers of beneficials are regularly added to the crop to prevent flare up of the pest population. This technique has been used successfully in glasshouse and nursery crops in Europe.

PROBLEMS ASSOCIATED WITH THE USE OF BENEFICIALS

There are many issues which make the use of beneficial arthropods much more challenging than the conventional or "3S" (squat, squint & squirt) approach.

1) Monitoring is an essential component of any IPM programme and its importance can not be over emphasized. Most crops have a range of pest species and an understanding of their biology and the inter-relationships between pests and their attendant beneficials is an important facet of practical IPM. Insufficient trained personnel are presently available to fill the increasing demand for scouting in IPM programmes.

2) The identification of pests and beneficials is far more critical in IPM than in chemical programmes because many of the beneficials are extremely host-specific. There is an urgent need for access to taxonomic services and good quality field keys for "on the job" identification of insects and mites.

3) More research is required to achieve a greater understanding of the pest and beneficial complex for each crop. Compatible pesticides charts, release rates, and time after spraying for the re-introduction of beneficials are all pieces of the puzzle that need to be fitted into place.

PROBLEMS ASSOCIATED WITH THE REARING OF BENEFICIALS

The mass-rearing of beneficial insect and mite species is fraught with traps and is not for the faint-hearted.

Seasonality. Many beneficials are required for critical times when the pest is active. This may be for only 2 or 3 months of the year. Often they have to be reared year round in order to supply a narrow market window of a few weeks.

Highly Perishable Product. Most beneficial species are extremely delicate and cannot be stored. What is produced today must be despatched today.

High Labour Input Required. The rearing of beneficials is very labour intensive and requires highly skilled and very dedicated personnel. Many beneficial species need some attention 7 days per week.

Highly Specific Product. Unlike broad-spectrum insecticides, most beneficial species are extremely host specific. This dramatically reduces the market potential and increases the relative cost of production. For instance *Leptomastix dactylopii* is an extremely efficient parasitoid of the mealybug *Planococcus citri*. However, where another species of mealybug is the major pest a different species of beneficial must be used.

Complex Production Systems. Most beneficial species have to be reared on their natural host. For instance *Leptomastix* can only be produced if its mealybug host is first reared on another host such as sprouted potatoes or pumpkins. This means that three living organisms are involved in the production of a single species of beneficial. For large numbers of beneficials to be ready at a critical time all living stages must be well synchronised.

Risk of Contamination. The host insect must be reared in isolation from the beneficial species. The danger of cross-contamination of stock cultures is always high and constant vigilance must be maintained to obviate this threat. It is usually necessary to maintain a constant source of pure back-up cultures to cover the eventuality of cross contamination.

BUREAUCRATIC THREAT TO THE INDUSTRY

Two aspects of bureaucratic interference now threaten the industry.

1) Australia now has legislation in place which could force the producers of beneficial insects to undergo a registration procedure for each beneficial produced. At present this could entail an up front fee of $20,000 and exhaustive efficacy testing for each species. Any such move would almost certainly cripple a small but potentially invaluable industry.

2) The importation of beneficial arthropod species for the control of exotic insect and mite pests has virtually ground to a halt under the weight of the recent Biological Control Act. At a time when the public is demanding reduced pesticide usage and we have 50 years of almost total neglect in the area of biological control to catch up on, this legislation is thwarting a critical aspect of alternative pest management options.

CONCLUSIONS

The successful use of beneficial insects as a strategy for IPM in glasshouses, nurseries and indoor atria will hinge on many factors:

1) The training and deployment of personnel with skills in monitoring and assessment of pest problems and their attendant beneficial species.

2) Need for support and funding for entomological research into the use of beneficial insects.

3) Cooperation at all levels of pest management from suppliers of beneficials to scouts, growers, and researchers.

4) An expansion of the range of beneficial insects available for control of key pests (e.g. thrips) — this may include the importation of suitable exotic species of proven performance.

5) An expanded range of "soft" alternatives to complement the use of beneficials, for example:

- Specific target pesticides such as insect growth regulators (IGRs)
- Biological pesticides such as B.T., virus formulations and nematodes
- Improved pheromone and baiting techniques for targeting specific pests
- Other controls such as coloured sticky traps

Some species currently in the pipeline are:

Species	Target pest(s)
Lindorus lophanthae	armoured scale insects
Aphidius colemani	aphids
Trichogramma spp.	various lepidoptera (caterpillars)

Some beneficials which could be subjects for future research and commercial rearing are:

Target pest(s)	Species
Armoured scales	*Encarsia* spp.
	Chilocorus nigritis
Soft scales	*Scutellista* spp.
	Metaphycus spp.
	Microterys spp.
Leafminers	*Dacnusia* spp.
Thrips	*Anthocorids* (*Orius* spp.)
	Amblyseius spp.
Various (esp.scales, mealybugs, mites, aphids)	lacewings

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Plant Protection—Management of Pest Control Techniques

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PLANT PROTECTION

What is Plant Protection? It is the management of pests of plants to maximize profit, pleasure, and leisure. Plant protection involves using detailed information about plants and pests to minimise the activities of pests so that they are not economically, aesthetically or environmentally important.

What are Pests? Pests are biological organisms capable of interfering with plant production. Pests include insects, plant pathogens, weeds, birds, and mammals. When managing the application of pest control techniques the term "pest" should be used to describe all the biological organisms capable of interfering with plant production.

What is Pest Control? The objective of pest control techniques has often been 100% (kill) of the pest or annihilation. This level of "control" may not be achievable and can be biologically undesirable. In the production of clean, pest-free nursery stock, it may be a requirement and this should be achieved using a combination of pest management techniques and not the over use of a single method.

CONTROL VERSUS MANAGEMENT

The propagation of plants for sale usually involves the production of aesthetically acceptable, pest-free material. The individual pest management (control) techniques are often used in isolation in an endeavor to eliminate pests and all pest related damage. For sound ecological reasons integrated pest management programmes, involving the use of as many management (control) methods as possible in a systematic programme of pest suppression, are being implemented.

The currently available individual methods of pest management must be thoroughly understood if they are to be used as components of a total programme directed at managing all pests important in propagation situations. Current pest "control" methods include:

- Physical and cultural control
- Varietal control (resistance to pests)
- Quarantine and hygiene
- Biological control
- Chemical control
- Integrated control

Physical and Cultural Management (Control). These methods include:

- Use of heat or irradiation;
- Open bench types and structures;
- Management of water use and humidity;

- Removal of infested plant material and pests;
- Planting and cultivation practices.

Varietal Control (Host Resistance). Host resistance to pests is an ideal form of long-term pest control. The aim should be to use resistance in the form of tolerance to major pests and not immunity. However, the number and diversity of pests makes incorporation of resistance to all pests impossible. Often plant propagation will be directed at producing plants which incorporate resistance to pests important in long-term crop production but not for pest problems occurring during propagation such as aphids and *Pythium*.

Quarantine and Hygiene. Quarantine is directed at either containing a pest within an infested area or keeping it out of an area. It is under utilized as a pest management technique. An understanding of pest mobility is essential for the successful use of quarantine and this when combined with hygiene practices can be very effective. The management of people movement is essential in the effective use of quarantine techniques. However, pests will endeavor to break down the quarantine procedures and systems put in place by humans.

The production and use of "clean" planting material is basic to the use of this method of pest management. Quarantine and hygiene should and can be used at the individual plant, propagation unit, nursery, local district, state and national levels to frustrate and minimise the activities of pests.

Biological Control. Biological control is the use of beneficial organisms to limit the activities of pests. This would seem to be an "ideal" form of pest management. However, it depends on the activities of beneficial organisms which may be unpredictable and follow peaks in pest numbers. Biological control will be more effective for some pests than for others, and it requires expert development, monitoring, and management. Because of the artificial situation in which plants are propagated, biological control may need to be supplemented and supported by other pest management techniques.

Other pest management methods, particularly the use of pesticides, will be used in a manner which is least disruptive to biological control agents and will involve determining their effects on the beneficials. Biological control agents may be cultured and formulated for application in host/pest situations. Products containing *Bacillus thuringiensis* are currently available for application using conventional systems of pesticide application.

The best aid to the effective use of biological control can be the strategic use of appropriate pesticides. Mixtures of biologicals and pesticides are being used effectively and viruses, bacteria, fungi, and nematodes are currently being investigated as biological control agents. The effective use of biological techniques requires on-going monitoring as pest, host, and environmental factors change in real situations.

Chemical Control (Management). The major factors influencing the successful use of chemical techniques are understanding the target (host/pest), the product, the method of application, and pesticide safety.

Target Identification. Precise target identification is essential. While pesticides are designed to act at a particular biochemical site in the pest, they are often unfortunately applied to the gross physical target—the total area occupied by the host, and not directed at the ecological target—the actual location of the pest.

Products. Pesticides are sophisticated materials designed to kill pests. Factors such as environmental conditions, formulations, and target location/behavior influence the activity of pesticides. Publications such as Peskem® and Garden Peskem® (Registered trademarks of Plant Protection at UQG) list products registered for use and should be consulted to assist with selection of the most appropriate pesticide. The directions on the product label, which is a legal document, must be followed and this along with the information contained in the individual product Material Safety Data Sheets (MSDS) provides a detailed product profile.

Application.Depending on the product formulation and target type and location, pesticides can be introduced to targets by granular, dusting, injection, wiping, or spraying techniques. Liquid formulations of pesticides are the most commonly used and spraying using hydraulic, centrifugal, or airshear systems are the most common methods of application. Attention to the choice, maintenance, calibration, and target orientation of the spraying system is essential for the successful use of chemical pest management methods. The use of selective methods of pesticide application will be an important future development.

Safety. Environmental and personal safety are particularly important in the safe use of pesticides. The selection, storage, handling, and application of products particularly the meteorological conditions at the time of application are important in maximising the effectiveness and minimising the environmental effects of pesticide usage. Personal safety includes understanding, using, and maintaining the protective equipment available. Pesticides are designed to kill biological organisms and must be handled accordingly. The development and use of a safety habit is essential for the safe and effective use of pesticides.

Problems of Chemical Control (Management):

- Over use and abuse of sophisticated products
- Public perception of risk
- Residues on products and in the environment?
- Pest resistance
- Used to cover poor management practices

STOP - READ THE LABEL, UNDERSTAND THE TARGET then use pesticides as part of a programme of pest suppression.

Integrated Pest Management (Control). The original definition by Stern et al. (1959), was "applied pest control which combines and integrates biological and chemical control. Chemical control is used as necessary and in a manner which is least disruptive to biological control." Biological control was used in its broadest sense to include all factors, except pesticides which may influence the development of pest populations. It is an environmentally compatible approach to pest control with the major features being:

- No reliance on a single method of pest management (control);
- No fire-brigade action using pesticides;
- No unnecessary usage of pesticides on a routine basis.

Plant protection is the development and implementation of integrated pest management programmes for use in particular plant production situations. This involves a detailed understanding of plants, pests, and pest management techniques in particular and the application of this information in a dynamic situation where all the interacting factors are continuously changing.

Plant protection could be likened to the construction of a building with the roof, representing an appropriate plant protection programme, which is economically feasible and environmentally acceptable, being supported by as many pillars, the individual methods of pest management (control), as possible. Detailed knowledge and common sense are essential components of successful plant protection.

PROFESSIONAL PLANT PROTECTION SERVICES

The effective management of pests in plant propagation situations requires an understanding of the principles of all the "control" techniques available for managing pests. Pests are dynamic and continuously changing and therefore plant protection programmes will require on-going professional monitoring and adjustment. Plant protection services are necessary if pests are to be managed successfully using environmentally acceptable and economically feasible plant protection programmes in plant propagation situations.

Full-time and continuing professional education programmes in plant protection are provided by the University of Queensland, Gatton College. The graduates are very active in providing plant protection services to clients from the wide range of plant production enterprises.

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Prospects for IPM in Greenhouse Ornamentals in Australia

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INTRODUCTION

Integrated Pest Management (IPM) in glasshouse vegetables is now well accepted in Europe (van Lenteren and Woets, 1988; van Lenteren, 1990) but IPM in ornamentals is more experimental. However, it is clear that the trend away from purely chemical control of insects and mites in glasshouses is irreversible and that much research is now focused on non-insecticidal methods (including natural enemies) to control pests in protected ornamentals. The latter include those grown in glasshouses, greenhouses (defined here as any enclosed structure), and in plastic tunnels. This paper provides a brief overview. It has its origins in a more comprehensive report, the result of an overseas study tour by the author in 1991 (Gough, 1992).

THE TREND AWAY FROM PESTICIDES IN GLASSHOUSES

In Europe and North America the trend away from purely chemical control to IPM/biological control in glasshouses is being driven by a number of factors. The examples below show that these trends are also important in Australia.

1) Increasing Miticide and Insecticide Resistance. Two spotted mite (TSM, *Tetranychus urticae* Koch) is a key pest of ornamentals and is notorious for its capacity to develop resistance (the ability of a strain of mites to tolerate doses of miticide which would normally be lethal). In continually warm conditions miticide resistance is a major problem. Thus, recent studies on the chemical control of TSM on roses (a very heavily sprayed crop) in Queensland and NSW (Gough, 1990; Goodwin et al., 1992 and unpublished data) have shown rapidly deteriorating control over the past 5 years. On some properties all registered miticides are now ineffectual because of resistance, which developed in under two years to some new compounds. Resistance has also been recorded overseas in some insect pests such as aphids, thrips, whiteflies, and dipteran (fly) leafminers.

2) Increasing Concern for Environmental and Work Safety Issues. The Dutch government is aiming for a 50% reduction in pesticide use by the year 2000, one reason being to reduce pollution of groundwater— IPM will be important in achieving this aim (J.J. Fransen pers. comm.; Van Lenteren, 1990). There is little weathering of pesticides by rain and sun in greenhouses. In the U.S.A., greenhouse re-entry time post-spraying is now as long as 72 h for some chemicals, which virtually precludes their use on ornamentals (Parrella, 1990). In Australia there is increasing concern about the lack of designated re-entry times for workers after greenhouse spraying. This is important in the warmer areas where workers are often scantily clad and there is a lot of skin contact with plants. Many growers

already minimise residue problems by spraying immediately before weekends or rostered days off, when staff are absent. However, it is likely that occupational health and safety bodies, now acutely aware of safety in the rural work-place, will formalise re-entry times. Already applications for the registration of new insecticides require information on re-entry periods established overseas.

3) Decreasing Availability of Insecticides. The Australian Federal Government plans to institute a new national registration system for agricultural and veterinary chemicals in mid 1992. Off label or minor uses, which are important for ornamentals because of the diversity of crops included under that heading, will become a Commonwealth responsibility. No matter how efficient, the new system is likely to be less flexible than the old where minor uses were approved by the various state departments of agriculture. There will also be a reassessment of older chemicals. It is not expected to be as draconian as that in the U.S.A. in 1989 which resulted in the loss of 20,000 pesticide registrations across that country (Parrella, 1990), but some chemicals may disappear. Companies are naturally hesitant to develop new pesticides for use in the ornamental industry because it represents only a small market on which to recover the significant costs.

4) Increasing Consumer Demand for Pesticide-Free Produce. In Holland and Germany consumers prefer cucumbers and other glasshouse vegetables on which pests are controlled biologically (Ramakers, pers. comm.). In Australia consumer groups are moving to encourage minimal pesticide usage on many crops, including apples and pears.

5) Increasing Encroachment of Suburbia on Ornamental Production Areas. This is a problem in the USA (Parrella 1990), and also in Queensland (where there have been several court cases because of spray drift from orchards). In a recent survey of flower growers in southeast Queensland, Parker (1992) found that most expressed concern about suburban encroachment. In California recent legislation requires monthly reporting of the use of all pesticides and public warnings before their application, both of which are very time consuming for growers (Parrella, 1990). Consideration was given to introducing similar legislation into Queensland but it was not proceeded with.

6) Biological Control Can be Cheaper and More Effective for Some Species Than Chemical Control. In European glasshouses TSM is effectively controlled by the Chilean predatory mite (*Phytoseiulus persimilis* Athias-Henriot), and the greenhouse whitefly (*Trialeurodes vaporarorium* Westwood) by *Encarsia formosa* Gahan (van Lenteren and Woets, 1988; van Lenteren, 1990).

IPM/BIOLOGICAL CONTROL

Greenhouses provide ideal conditions for the growth of both pests and their natural enemies. Confinement leads to easier release of beneficials which may, with efficient prey-searching behaviour, lead to effective biocontrol. Greenhouses also provide ideal conditions for the development of pesticide resistance and, if it eventuates in a key pest, predators, parasites, or insect pathogens provide the principal means of control. However, crops are rarely attacked by a single pest. The biological control of a key species must therefore be integrated with the control of other pests and diseases using compatible chemicals, natural enemies, and

pathogens, resistant plant varieties, etc. IPM focuses on integrating a range of control options with biological control, because the action of the natural enemies is often the most important and easily disrupted (Way, 1973). By screening and good hygiene many important pest species can be largely excluded from enclosed structures, often an essential prerequisite to successful IPM. Widespread biological control in glasshouses is contingent upon the large scale production and sale of beneficials (predators, parasites, and pathogens). This is an important industry in the northern hemisphere (e.g. there are five producers in the UK (Helyer and Richardson, 1991) and 60 in the U.S.A. (Raupp et al., 1992). There are currently at least four producers in Australia.

Extent of IPM in Glasshouses. Biological control and IPM of insect pests and mites in protected (glasshouse) vegetables is now widespread and successful with some 12,000 ha involved worldwide (van Lenteren, 1990). IPM in ornamentals is much more experimental and has had varying degrees of success. However, Wardlow (pers. comm.) is confident that biological control/IPM on glasshouse ornamentals can be a reality. In southern England insects and mites are under almost complete biological control in several very large nurseries, giving credence to his opinions. In these nurseries, biocontrol is more expensive than chemical control but quite acceptable to nursery management (Wardlow, pers. comm.). This is a result of good applied research and extension and close cooperation with growers. The latter are prepared to take some risks and want to reduce pesticide usage. In Germany, Albert (1990) has also reported some success. My impression is that the Dutch have a philosophy of not recommending IPM until it is proven under most conditions (van Lenteren, 1990), and so IPM on ornamentals in Holland is not widely used yet. This rationale can be adopted where excellent experimental glasshouses (on a commercial scale) and adequate research staff are available. When this is not the case (as in most parts of Australia) one is often forced to experiment on growers' properties and to promote commercial use of IPM before every problem is ironed out. While there are obvious drawbacks, a bonus is that growers are innovative and persistent, and often make a major contribution to the success of the programme. My impression in the U.S.A. is that IPM is much discussed but only beginning to be used. Whatever the present status, greater use of non-chemical methods (including biological control) on greenhouse ornamentals is inevitable.

IPM IN AUSTRALIAN ORNAMENTALS

Present Status. At the 1991 conference "Australian Horticulture — Clean and Green in the 1990s" it was clear that limited IPM in ornamentals is developing significant momentum in Australia. The predatory mite (*P. persimilis*) is now used by about 50% of flower growers in southeast Queensland (Parker, 1992) because of severe miticide resistance. Here it can be very effective (Gough, 1991). *Phytoseiulus persimilis* is also used in NSW (Goodwin et al., 1992) and Victoria (Osmelak and MacFarlane, 1992). However, as insecticide usage is reduced to allow these predatory mites to be fully effective, other pests often proliferate. Thus, mealybugs, thrips, and whiteflies have increased in pest status in Queensland and must now be controlled in a non-disruptive manner.

The Future in Australia. In those areas where miticide (and insecticide) resistance is not a major problem, chemical control will continue to dominate. For those areas where chemicals are not effective (or can not be used), Australia's current research and development on IPM in ornamentals needs expanding beyond the use of *P. persimilis*. Where TSM is resistant to chemicals, ultimate success with preditory mites will depend on the integration of a range of control strategies including the use of natural enemies, insect pathogens, and insect growth regulators (which selectively control some homoptera and gross feeders e.g. caterpillars) for secondary pests. As mentioned previously, hygiene and pest exclusion are very important. Indeed biological control of some pests will be impossible if they are able to constantly migrate, unimpeded, into the greenhouse. Success also depends on biocontrol companies increasing their range of natural enemies. The commercial production of beneficials is expensive and needs early coordination with developmental research and extension. On several occasions biocontrol companies began producing new parasites for greenhouses in Australia, but production was curtailed because there were no markets due to minimal research and development or advice to growers. Developing IPM in ornamentals is a long term commitment and will continue only if funding support is available. The nursery and flower industry in Australia is very large (e.g. in Queensland alone the total value is worth more than $200 million per annum) but the funds available for research are not commensurate to its size.

Australia is fortunate that it does not have several key pests which greatly complicate IPM, such as western flower thrips (*Frankliniella occidentalis* Pergande) and several species of leafminers (*Liriomyza* spp.) which occur in North America and Europe. Cotton or sweetpotato whitefly (*Bemisia tabaci* Gennadius) does occur here but our strain appears to be innocuous, unlike those of the U.S.A. and Europe. *Thrips palmi* Karny appears to be confined to the Northern Territory. Several important exotic beneficials are already in Australia (Gough, 1992) but are used rarely or not at all in ornamentals. The Federal Government has stringent import requirements for biocontrol agents which host-specific parasites normally meet, but polyphagous predators are difficult to import. Consequently, we need to examine the native fauna for potential predators such as anthocorid bugs (*Orius* spp.) and chrysopid larvae, which are common in Queensland field crops and are used as greenhouse predators overseas. Small ladybirds, *Stethorus* spp., are commonly found in unsprayed greenhouses in southeast Queensland and feed on TSM. Australia has many species of phytoseiid mites and some of these species already provide effective biocontrol on other crops (e.g. James, 1990). Workers in the northern hemisphere have discovered many of their best beneficials locally, in unsprayed glasshouses. We should follow their example.

It is clear that once growers achieve successful control using beneficials, they are prepared to persist and experiment. They are innovative and take pride in their success. Finally, the Australian ornamental industry and various government funding bodies have recognised the importance of IPM and made it a high priority area for research. All these factors are a cause for optimism that IPM in ornamentals, and especially in greenhouses, can be expanded.

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Control of Two-Spotted Mite by Predatory Mites

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INTRODUCTION

The Two-Spotted Mite (TSM)—*Tetranychus urticae*. Two-spotted mite belongs to a group of eight legged plant-eating mites. The young and older mites are pale green with two dark patches on their backs. The adults are about half a millimeter in length and are best viewed with a hand lens. Their eggs are round and pearly white. Two-spotted mites suck out the cells in the leaf, causing minute, yellowish, feeding marks which may join together causing leaves to shrivel and die. Once damage occurs, it will remain, as the leaf cannot repair itself.

Two-spotted mite is a major pest of a wide range of horticultural crops. Nurserymen can suffer serious losses due to the leaf scarring and stunted growth that these mites cause. Chemical controls have been the norm until the last few years. These are becoming less reliable as mites have developed high levels of resistance to some, and at least some resistance to most, chemicals. This process has been accelerated in recent years with the withdrawal from sale of some useful miticides and the consequent higher pressure placed on the remaining chemicals. Further, some chemicals are phytotoxic to some species, so that mite control can become a nightmare. Added to the difficulties of chemical control is the increasing dislike of using chemicals by both workers and owners. The use of the predatory mite, *Phytoseiulus persimilis*, for the control of two-spotted mite has enabled many nurserymen to escape from this "no-win" situation. This paper will outline the use of predatory mites in the nursery situation.

PREDATORY MITES

The Predatory Mite—*Phytoseiulus persimilis*. This predator has been commercially produced overseas for more than 20 years and in Australia for over 10 years. It feeds voraciously on two-spotted mite. Its effectiveness has enabled its use in a wide range of crops. These include strawberries, cut flowers, hops, pawpaws, glasshouse and field vegetables, deciduous fruits, and ornamental. It is now not uncommon for it to appear in a nursery where it has never been introduced. For all the crops mention above, the environment of the nursery is the most favorable to the predator, it thrives in warm, humid, and semi-shaded conditions.

The adult predatory mite is orange, while the young are colorless. Both are pear shaped and fast moving. The oval-shaped, orange-tinged predator eggs are much larger than mite eggs. Adult predators feed on mite eggs, young, and adults. They pierce the body and suck out the contents. Even though predators are only slightly larger than mites, an adult can destroy 20 young or 7 adults per day and at 25°C will multiply twice as fast as TSM. Predators will feed and multiply in an area until mites have been almost eliminated. They will then disperse in search of more mite colonies. Continuous foliage will therefore assist their movement through the nursery. It is worthwhile grouping mite-susceptible plants into one or several

areas. This will provide the predators with more opportunities for survival and persistence than would numerous small areas. This practice also simplifies monitoring and spraying procedures.

How to Use Predatory Mites. Small- to moderate-sized nurseries order predators as they require them, but larger nurseries are beginning to adopt the regular-release technique used by many cut flower growers. This latter method ensures that predators are always in the nursery ready to move in on new mite infestations. It also encourages the identification of mite infestations by employees and the subsequent early dosing with predators before any significant damage occurs. Either way, an initial general predator release into the mite infested areas is recommended.

Chemical Residues Toxic to Predatory Mites. Chemicals toxic to the predatory mite must have had time to disperse before predators are released. The most toxic are the synthetic pyrethoids (Mavrik®, Ambush®, Decis®, Ripcord®, etc) which may need up to 8 weeks to disperse. Folimat®, Phosdrin®, Orthene®, Monocrotophos®, Supricide® will need 2 weeks, and Kelthane® and Rogor® will need 1 week. Guidelines for the use of chemicals are available from predatory mite suppliers.

Inspecting the Nursery for Two-Spotted Mites. Unfortunately, many nurserymen use predators as a last resort after they have been unable to adequately control mites by chemical means. The preferred timing for the introduction of predators is before mites have caused significant damage. In this way, miticide spraying can be completely avoided. Mites must be present in low numbers or the predators will be unable to establish in the crop. If mites are easy to find, or more precisely, if 30 lower, older leaves were inspected and 3 to 5 were found to have mites (any mites at all) then predators could be introduced. Predators should be released into mite infestations soon after they are discovered in the nursery. It is therefore important, particularly in larger nurseries, that workers be taught to identify mites (and other pests) and the damage they cause.

Introducing Predatory Mites. If overhead irrigation is required, then it should be applied before introducing predators rather than soon after. Apply any necessary insecticide sprays several days before the anticipated release of predators. Likewise, if mites are beginning to cause significant damage, a predator friendly miticide should be applied to knock down the mite numbers before the introduction of predators.

Predators are despatched in packs of various sizes but the standard is the "Commercial Pack" which contains a minimum of 10,000 predators (all life stages) and is enough to treat about 200 square meters of lightly-infested plants. The predators are despatched on bean leaves. These are packed into a cardboard cylinder and sent via Australia Post Express Courier. Each cylinder contains 100+ bean stalks, each with three leaves. Gently separate the leaves and tuck them into the foliage at the level of the mite infestation. Place more bean leaves in those areas with more mites.

What to Expect. Expect predators to be hard to find for two weeks after release. Mark a few sites where bean leaves were placed and regularly check these areas to help assess the predators' development. Mite numbers will continue to increase after predator release, but predators will soon appear amongst most mite colonies

and be easily found after 3 to 4 weeks. Mite numbers will then level off and then suddenly fall to very low, if not undetectable, levels. The predators will also disappear and may move into the surrounding vegetation. This can help provide a barrier against future infestations. Reinfestations are likely from time to time. The predators may have missed a few mite eggs, so that these will gradually develop into another outbreak. Predators will often return and quell the outbreak, unnoticed by the nurseryman. But this cannot be taken for granted. Regular checks should be maintained, as, mites can move readily on the wind, come in on new plants, or be unwittingly transported by workers who have been in a mite infested area.

Environmental Factors Affecting Mite and Predator Populations. Predators thrive in warm to hot and humid conditions while TSM do best in very hot, dry conditions. Nursery conditions are normally in the most favorable range for the predator, which will therefore be able to breed much faster than the TSM. Plants close together or with dense foliage automatically provide the microclimate desirable to predators. Plants with less dense foliage or plants just after pruning have lower localized humidity levels, so these areas should be checked regularly for mites, especially during hot, dry conditions. Windbreaks or roll-down screens should be used to prevent hot dry winds from blowing through the nursery. Screening the sides of shade and plastic houses can also significantly reduce the movement of moths and grasshoppers into the nursery.

CONTROLLING OTHER PESTS

With Chemicals. Care should be taken with the use of chemicals. Predators will establish faster in an unsprayed situation than when pesticides are used. Study the chemical guidelines provided (see Table 1) and avoid the application of insecticides until at least 2 weeks after predator release. Predators are very effective and quick-acting in the nursery environment so it should not be difficult to with hold insecticides for a few weeks after predator release. Carbaryl is the safest chemical insecticide to use with predators and should be used in preference to those which are more hazardous, and especially until predators have become well established. If more "hazardous" sprays need to be applied before the predators have controlled the mites then spray penetration should be minimized. This minimisation enables the maintenance of a safe haven for predators in the lower foliage. It should be noted that in warm, humid conditions predators will recover very quickly from setbacks due to chemical sprays, while in cool or dry conditions recovery will be much slower.

If TSM reaches damaging levels after predator release, a predator-compatible miticide can be applied to reduce mite numbers. This enables the predator to catch up and eliminate the remaining mites.

Most fungicides are safe to use with the predator. There are a few notable exceptions—Mancozeb is "partly hazardous" and should not be used repeatedly. Benomyl and Morestan are "hazardous" and should not be used. By spraying only those areas that need to be sprayed, there will be minimal disruption to the resident predators and other beneficial species. In addition, this limited spraying minimises the chances of mites developing resistance to chemicals. In this way, a longer useful life will be obtained from chemicals and those such as Torque® and Omite® which are relatively safe to predators can remain a useful tool in the future.

With Beneficial Species. The chemicals recommended for use with predatory mites are also less harmful to many other beneficial species. The synthetic pyrethroid group and some of the more residual organophosphates are particularly hazardous to beneficial species. The removal of the synthetic pyrethroid group and organophosphates from the spray schedule will enable the movement of beneficial species into your nursery. Occasional use of the synthetic pyrethroid group and organophosphates may be necessary if "less toxic" means are ineffective against a specific pest.

The adoption of predators for TSM control often leads growers to reduce overall chemical inputs and to the consideration of other biological and minimum-chemical control techniques. Growers express interest in knowing more about both naturally occurring and commercially available biological control agents. To this end, some key pests and their common natural enemies are listed below.

Key Pests and Their Predators.

Aphids.

- *Aphidius colemani* (and other similar species) - parasitic wasp, about 3 mm long, lays eggs which hatch into larvae and develops to mature stage inside the aphid, forming a shell called a"mummy" in the process. Each female can sting 60 aphids. Feeds on nectar.
- *Syrphus* spp. - hover fly larvae, about 6 mm long, feed on aphids.
- *Harmonia conformis* - common spotted ladybird.
- *Coccinella repanda* - transverse ladybird, both adults and larvae feed on aphids.
- *Micromus* spp. - lacewing larvae.

Two-Spotted Mite (Tetranychus urticae) and Close Relatives.

- *Stethorus fenestralis* - small black ladybird beetle; a voracious feeder which usually does not appear until infestation is well advanced.
- *Phytoseiulus persimilis* - predatory mite, time of introduction into Australia unknown but now virtually naturalized. Adult is about 0.6 mm long, orange, pear shaped, a voracious feeder of all life stages of TSM. Commercially reared for use in wide range of crops.
- *Amblyseius* spp. - native predatory mites feed on eggs and adults.
- *Syrphus* spp. - hover fly larvae, about 6 mm long, feed on mites and eggs.
- *Micromus* spp. - lacewing larvae.
- unidentified, small fly larvae.

Lepidopteran pests.

- *Trichogramma* species - tiny egg parasites which in unsprayed situations can destroy high numbers of moth eggs. At present being commercialized.
- Various parasitic wasps which attack the larval stages.
- *Micromus* spp. - lacewing larvae feed on eggs and small larvae
- Assassin and damsel bugs are general predators which feed on moth eggs and grubs

Table 1. Chemicals for use in conjunction with predatory mites.

Chemical[1] (Trade names only)	Targeted pest	Toxicity to predators[2]	Safe to spray: Days before release	Safe to spray: Days after release	
Insecticides					
Dipel, Thuricide	Caterpillars	Safe anytime	0	0	
Carbaryl, Bugmaster	CP, thrip, Mealybug	Safe	2	4	
Pirimor	Aphids	Safe	2	14	
Lorsban, Dursban	CP, Scale, Grasshoppers	Partly hazardous	6	21	see note 1
Maldison	CP, Thrip, mealybugs	Partly hazardous	7	21	see note 1
Thiodan, Endosan	CP, thrip, aphid	Partly hazardous	7	28	see note 1
Natural Pyrethrum	CP, thrip, aphid	Hazardous	3	28	see note 2
Lannate, Nudrin	CP, thrip	Hazardous	3	28	see note 2
Miticides					
Torque	Mites	Safe	2	7	
Apollo	Mite eggs	Safe	2	7	
Calibre	Mite eggs	Safe	2	7	
Tedion	Mite eggs	Safe	2	7	
Wettable sulphur	Mites	Safe	2	7	
Omite	Mites	Partly hazardous	2	14	
Fungicides					
Most fungicides		Safe	2	4	
Mançozeb	Powdery mildew	Partly hazardous	2	1	see note 1
Benlate, Moresten	Powdery mildew	Hazardous	7	42	see note 3

[1] Check chemical registrations and phytotoxicity before spraying.
[2] Avoid insecticides for as long as is practical after introducing predators.

Notes:

1) Avoid these insecticides until predators are easy to find in mite colonies.
2) Lannate and natural pyrethrum although hazardous to predators break down quickly. They can be used occasionally if predators have controlled mites and pray penetration is minimized.
3) Benlate and Morestan should not be used.

Glasshouse White Fly.

- *Encarsia formosa* - tiny parasitic wasp which lays its egg into the whitefly scales. At present being commercialized.

Scale.

- Ladybirds - some species feed on scale.
- *Aphytis* spp. - small parasitic wasps, some species commercially available.

Mealybug.

- *Cryptolaemus montrouzieri* - predator of mealybug, very effective when mealybug populations are high. Commercially available.
- *Leptomastix dactolopyii* - wasp parasite which attacks only citrus mealybug, *Planococcus citri*, which is the most common species found in southern Queensland. Commercially available.

CONCLUSIONS

A prerequisite for the successful use of predatory mites (and other biological agents) is a commitment from the nursery manager to adhere to the recommendations for use. There must be a willingness to venture into the unknown; to change chemical spray regimes, and to find predator-compatible ways of overcoming problems. The adoption of a biological pest-control method invariably achieves the desired and very satisfying result of controlling a pest without using chemicals. As the use of predatory mites clearly has many advantages over chemical controls, it is obviously a technique that is here to stay. Further, success with predatory mites encourages growers to search for and adopt other minimum-chemical, pest-control methods.

Deflasking Micropropagated Plantlets

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INTRODUCTION

Micropropagation is the multiplication of plants under sterile conditions. Plant parts, including cell, bud, stem, and leaf, can be used as explant sources. The desired piece of tissue is placed on an appropriate culture medium and induced to produce shoots and roots under controlled laboratory conditions. Practical applications include the rapid multiplication of plants, the multiplication of otherwise difficult to propagate plants, and the propagation of rare and endangered species. In addition, plants in culture are easy to import and export as the small, lightweight containers are easy to handle, and contain no soil.

DEFLASKING

The following method is used by Redlands Greenhouses with excellent success, particularly for herbaceous and tropical foliage plants.

Hygiene. Sanitation is of vital importance when transplanting from tissue culture. As the plants have previously been kept in a pathogen-free environment, they are highly susceptible to fungal and bacterial agents. Prior to deflasking, we disinfect the propagation area with Hibitane. Tools and equipment are also sanitised.

Media. Our standard propagation medium consists of peat and perlite (1 : 1,v/v). This medium is usually mixed by hand, 3 cubic metres at a time. No nutrients are added at this time. Dolomite lime is used to bring pH to 6.0.

Containers. Two types of continaers are used.

- Fifty-milliliter plastic tubes packed into wire trays which hold 100 tubes;
- Plastic liners for standard seedling trays 30 × 26 cm, each having 48 cells.

Sterilisation. Once the medium is packed into the containers, the trays are stacked four high and treated for 48 h with methyl bromide under a tarpaulin. The stack contains 60 trays holding a total of 6,000 tubes. Once aired, the trays are taken to the propagation room.

Equipment Needed for Deflasking. Clean basin, warm water (approximately 40°C), scalpel, atomiser bottle, dibble stick, disinfectant, and clean newspaper are needed.

Method. Sanitise the scalpel and dibble stick in a container of disinfectant. Place clean newspaper on the work bench and fill the basin with tepid water. After opening the flask, gently extract the plants and place them in the warm water. In most instances the culture medium (agar) will adhere to the root system. We prefer

to wash off all agar. Preferably this process should be carried out under running water in a trough. This should eliminate any chances of cross-infection should the agar or plants be contaminated. This facility is not available in our propagation area, so we use the basin method. Any contaminated flasks are left until last, again to avoid risk of cross-infection. As a precaution, fungicide or disinfectant may be added to the water.

Trials. In 1984 we conducted trials with *Spathiphyllum* to ascertain possible benefits of leaving the agar, which may still have some nutritional value, intact on the roots. There was no difference in the growth of roots or plants with or without agar. We did find, however, that the plants were easier to process when completely bare rooted.

Once the agar has been removed, place the plants on the newspaper. Some division may be necessary at this stage. Quite often with tissue culture, two or more plantlets are joined on one piece of callus tissue with some roots projecting from the callus pad. These plantlets are easily divided by using a sharp scalpel and slicing cleanly between the plant crowns. We do endeavour to leave a root piece on each plant if possible. This method of division has not proven detrimental to the subsequent growth of plants. The root system can also be trimmed if it is too extensive, as it is often difficult to insert plants with long roots into the medium. Again this seems to have no detrimental effects as the roots of tissue-cultured plantlets are rather ineffective at absorbing moisture for some days after transplanting. The plants are too fragile to be inserted into the medium without the use of a dibble stick.

At no time during the transfer stage should the plants become stressed. They have been used to a high humidity environment and deteriorate rapidly under normal glasshouse conditions. Spraying the deflasked plants with water from an atomiser will alleviate this problem until they can be placed in a humid environment. Tools are disinfected after each flask and clean newspaper and water are used for each flask.

Grading. The plantlets should be graded at planting, so as to avoid problems of varying plant sizes at the potting-on stage.

Environmental Conditions. Under controlled laboratory conditions, the relative humidity remains at 100%. Because of this, the plantlet leaves are immature, with no protective waxy cuticle and their stomata remain open, leaving the plant unable to control water loss. Therefore, high humidity conditions are essential during the first two weeks to avoid stressing the newly transferred plants.

To achieve a humidity of at least 95%, we at Redlands Greenhouses have designed polythene tents under which the plants are reestablished. The frame is constructed from rigid PVC tubing and suspended by wire from the framework of the glasshouse. Opaque plastic is draped over these structures to form a tent, 8.9 × 1.2 × 1.6 m. The tents are situated inside the propagation glasshouse on benches that are heated with hot water. These benches are covered with black plastic which extends to the concrete floor. This arrangement helps trap heat and the plastic is easily sanitised between crops. The opaque plastic of the tent extends past the bench tops to keep in the heat and to allow some sealing.

Misting nozzles, controlled by a time clock, run the full length of the benches inside the tents. The plants are misted for 8 sec every 10 min. The nozzles are

regularly cleaned and checked for blockages to ensure that there are no dry spots. Inverted wire trays are placed over the trays containing the plants. On top of these trays, newspaper is spread, one-sheet thick. This newspaper:

- Reduces light intensity and so prevents the plants from being burnt. Light intensity in most greenhouses is far higher than it is in tissue culture labs.
- Ensures that heavy water droplets do not damage the plants and helps avoid over wetting.
- Increases the humidity level around the plantlets and keeps it constant.

Because fungi and bacteria thrive under these conditions, it is very important to inspect the plants every morning. Any diseased material should be promptly removed.

Hardening-Off. The newspaper can be removed after 7 days. The following week the sides of the tent can be raised during the hottest part of the day, and lowered again at night. This procedure is continued, with the sides being raised for extended periods each day, until the plants have hardened-off sufficiently to allow the tent to be raised permanently. The hardening-off time varies between species, but it usually takes 3 weeks. Misting can also be reduced during this stage.

After-Care. Once established, the plants are transferred to the general indoor hardening- off section to grow until they are ready for potting on. During this time they are liquid fed through the watering system and will benefit from two to three grains of nutricote per tube. Some species, e.g. *Platycerium*, will continue to multiply during this stage. The smaller plants are easily removed for replanting.

CONCLUSION

No doubt many nurseries have their own methods of re-establishing tissue-cultured plants. This method works well for us and ensures a high survival rate.

New Fire Blight and Scab Resistant Pyracanthas

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A *Pyracantha* breeding programme was started in 1982, to obtain resistance to fire blight (*Erwinia amylovora*) and scab (*Spilocaea pyracanthae*), and frost resistance. The ornamental criterion was a heavy long-lasting fruiting period. Cross pollination of different species and cultivars in INRA'S collection produced hybrids tested against scab and fire blight. Best hybrids were then cloned and tested again in a glasshouse. Observations were made on flowering and fruiting abilities. All hybrids have endured two hard winters with temperatures falling down to -15°C without snow protection. Two cultivars were selected and released to trade.

INTRODUCTION

Pyracantha is a favorite landscape and garden shrub because of the brightly coloured berries carried through the winter. They are mainly used as formal hedges or in free forms and more rarely as wall-covering plants.

Pyracantha is a member of the rose family (Rosaceae) and of the subfamily Maloideae which includes *Malus*, *Pyrus*, *Crataegus*, *Sorbus,* and *Cotoneaster*. This subfamily is a specific host of the fire blight bacteria (*Erwinia amylovora*) which was first discovered in the U.S.A. Extensive evaluation of the susceptibility of commercial species and cultivars of several genera has been undertaken in Angers by the Plant Pathology Research Station (Paulin, 1990).

As antibiotics are not allowed to be used to control plant disease in this country, only preventative techniques may be used to control fire blight. Breeding new cultivars resistant, or highly tolerant to fire blight, is an important part of prevention. Programmes have been developed on apple (Lespinasse and Paulin, 1989), pear (Thibault and Paulin, 1984) and *Pyracantha* (Cadic et al., 1989).

The first fire blight resistant cultivars of *Pyracantha* were released by Egolf between 1966 and 1986. Six cultivars have been described: 'Shawnee', 'Mohave', 'Navajo', 'Teton', 'Apache' and 'Pueblo' (Egolf, 1966; 1970; 1978; 1987a; 1987b), but this author is unaware of any information published on the inoculation procedure or the strain of *E. amylovora* used by Egolf to test them. In 1975, a breeding programme was initiated in The Netherlands (Bouma, 1990) but so far no cultivar has been released to the trade.

MATERIALS AND METHODS

Breeding strategy is summarized in Table 1. Crosses between 33 clones in the INRA collection were made in 1982 and 1983 in 126 combinations, including selfing. Young seedlings bearing four or five leaves were then tested against scab in a glasshouse. Scab had been collected on susceptible taxa then cultivated on an artificial medium and induced to produce spores (conidia). These were sprinkled on

leaves and susceptibility was screened. Only young hybrids without scab symptoms were retained for a second screening.

Table 1. Pyracantha breeding strategy.

1982 – 1983	Hybridizations in Angers
1983 – 1984	Glasshouse selection for scab resistance in Angers
1983 – 1984	Selection for fire blight resistance at seedling stage in Dax Field plantation
1985 – 1989	Repeated field inoculations, preselection, and cloning of preselected hybrids
1986 – 1992	Glasshouse tests in Angers. Field plantation for further observations

At this time, fire blight was not yet present around Angers so it was impossible to perform inoculation experiments. Hybrid seedlings were taken to Dax in the southwest of France which is in a fire blight area. Seedlings were top leaf inoculated with infected scissors using a French strain (CFBP 2045) at a concentration of 10^8 living bacteria per ml. Surviving plants were then planted into the field and inoculated again in the following years. Actively growing shoots were tip injected as soon as possible with a new French strain (CFBP 1430) at a concentration of 10^9 living bacteria per ml. Symptoms were scored from 0 to 3, 0 meaning no symptom, 1 meaning necrosis of less than 1/3 of the inoculated shoot; 2 meant 1/3 to 2/3 and 3 meant complete necrosis. Each seedling was inoculated 5 times on more than 30 shoots. Seedlings were selected for further screening on the basis of these scores. Ten rooted cuttings of each selected seedling were containerised and placed in a controlled glasshouse at Angers. Inoculations, at a concentration of 10^9 bacteria, were then repeated using a French strain (CFBP 1430) and an American strain (CUCM 273) of *E. amylovora*. The number of inoculated shoots showing necrosis and the size of necrotic patches were scored. Common cultivars were used as control and only the best seedlings were selected to be field planted for further observations of ornamental qualities.

RESULTS AND DISCUSSION

Resistance to scab is quite easy to assess. Susceptible plants are quickly covered by a dark olive green mycelium while resistant plants remain free. From 7111 contaminated seedlings, 3273 were judged resistant. This resistance looks quite stable both in Dax or Angers. On resistant plants, conidia spores are unable to germinate or germination and mycelium development are quickly and actively stopped by surrounding tissues.

Resistance to fire blight is unlikely to exist and it would be better to speak of tolerance. Even tolerant cultivars may express symptoms when grown in conditions that favor the disease, or if inoculated with very high concentrations of conidia. By repeating field inoculations and using two strains in the glasshouse we tried to overcome environmental effects to assess the true potential susceptibility.

It was found that highly susceptible clones must not be used in crosses. For instance, all progenies from *P. angustifolia* have had to be discarded after the first test. One of the best parents used was the American selection 'Shawnee' and

especially in combination with the French cultivar 'Mozart' a cultivar of from *P. atalantoides*. Results from a glasshouse inoculation made in March 1989 show that selected hybrids were more effective at resisting the symptoms of fire blight than the commercial cultivars in the INRA collection (Table 2).

The range of susceptibility to fire blight follows a continuous genetic variation and environment drastically modulates plant responses to infection so that it is likely that several genes are involved in fire blight tolerance. Improvement of resistance to fire blight would then be reached by accumulating those genes by performing recurrent crosses between the more resistant hybrids.

Of the 3000 hybrids originally tested against fire blight only 229 appeared to have disease resistance better than existing cultivars.

Table 2. Susceptibility to two strains of fire blight: a comparison of selected genotypes to 45 known cultivars.

	Strain CFBP 1430			Strain CUCM 273			Total both strains		
	Genotype[1]			Genotype			Genotype		
	LIS[2]	LN[3]	%	LIS	LN	%	LIS	LN	%
A	6803	1904	28.0	6707	1902	28.4	13510	3807	28.2
B	9601	4047	42.2	10030	4116	41.0	19631	8163	41.6

[1]A = Selected hybrids population, B = 45 cultivars from collection.
[2]LIS = Length of inoculated shoots in cm.
[3]LN = Length of necrosis in cm.

They all survived the severe frosts of two consecutive winters during which temperature fell to -15°C. Under the same climatic conditions, *P. angustifolia* has been killed, aerial parts of 'Navajo' and *P. crenatoserrata* 'Graberi' were killed, and *P. atalantoides* and relatives were slightly injured (Bertrand et al., 1992).

Up to now, two cultivars have been released to the trade. Both are owned by INRA and SAPHYR, the group of nurserymen who financially supported part of the breeding program.

Pyracantha 'Cadange' SAPHYR® Orange comes from a cross between *P.* 'Shawnee' and *P. atalantoides* 'Mozart' a slow growing heavy flowering and fruiting cultivar. Fruits are orange (RHS 25A to 28A), colouration is early. It is a medium-sized cultivar.

Pyracantha 'Cadrou' SAPHYR® Rouge originates from the same cross. Fruits are red (RHS 46B) turning to orange. As compared to other red-fruited firethorns, this cultivar has smaller leaves and fruits are not hanging down.

Both cultivars have been described (Bertrand et al., 1992). They were put to the trade in 1989. To fill the cultivar range, a yellow fruiting form will be introduced next year. Nurserymen are also selecting hybrids with a stronger growth and perhaps with a more erect habit.

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Cotoneaster dammeri: Fire Blight (*Erwinia amylovora*) Resistant Cultivars in Germany

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SITUATION IN GERMANY

The bacteria disease fire blight first appeared in 1971 in Schleswig - Holstein on *Crataegus monogyna* and *Pyrus* fruit trees. It spread south, reached Hamburg in 1974, Westfalia in 1975, and finally the southern parts of Germany in 1981 (Baumm, 1989). Initial attempts at control included strict eradication of *C. monogyna* from windbreaks, especially in nurseries and around infested locations. Commercial production of common hawthorn was banned. These restrictions could not stop *Erwinia amylovora*. Nowadays people have learned to live with the disease, which is mainly found in Germany on *Chaenomeles*, *Cotoneaster*, *Crataegus*, *Cydonia*, *Pyrus*, and *Photinia*.

CHEMICAL CONTROL

Antibiotics cannot be used for plant protection in Germany. Copper is used as a protective agent but has some disadvantages:

- Needs to be sprayed frequently
- Accumulates in the soil
- May inhibit plant growth
- Phytotoxicity problems

Since 1982 we have been working with the prognosis model based on the work of Billing (1974) to optimize/minimize the use of copper during the growing season in relation to weather (Brulez and Zeller, 1981). Different plant extracts (*Berberis*, *Mahonia*, *Rhus*) have also shown an effect on fire blight under field conditions when used as prophylactic treatments. However, they are not yet used in the nurseries (Mosch and Zeller, 1989).

RESISTANT CULTIVARS

Work on resistant *Cotoneaster* cultivars started in the late 1970s by Persiel and Zeller at the Institute for Horticultural Plant Breeding in Ahrensburg (close to Hamburg) with *C. dammeri* var. *radicans*. This species is not very susceptible to fire blight under German conditions. Occasional problems occur during nursery production but rarely afterwards. Following artificial testing, 16 clones of *C. dammeri* var. *radicans* were further tested for ornamental value in the plant selection section of the Versuchs - und Beratungsring für Baumschulen in Pinneberg. After another four years of testing, two fire blight resistant clones were selected and named:

1) 'Holsteins Resi'. Very similar to *C. dammeri* var. *radicans* with leaves 3 to 4 cm long and about 2 cm wide, and growth up to 25 cm high. The cultivar is a very good

groundcover because of its ability to make a nice, close carpet.

2) 'Thiensen'. Very similar to *C. dammeri* 'Major' with leaves 4 to 5 cm long and about 2.5 cm wide. This cultivar also makes a nice and low carpet.

Both cultivars are under plant breeders rights in Germany. Only a group of 16 growers are allowed to propagate them. Interplant in Leersum (Netherlands) holds the breeders rights for the Netherlands, Belgium, and Luxembourg and A. Briant for France. Negotiations are under way with growers in Great Britain and the U.S.A.

FUTURE

At the moment we are testing more than 100 selections resistant to fire blight similar to *C.* × *watereri* 'Cornubia' and *C. salicifolius* var. *floccosus*. The breeding programme with these plants is very difficult, because they are very susceptible to fire blight. The first results are promising, so resistant selection may be available in a few years time.

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The Assortment of Ornamental Tree and Shrub Nurseries in Poland

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CLIMATIC AND BOTANICAL REGIONS

There are five climatic regions in Poland: the western zone, the transitory zone, the eastern zone, the southern submontane zone, and the montane zone.

The western zone has a moderately warm climate under oceanic influence, with rather mild winters and a long growing period. On average there are less than 30 days with the temperature below 0°C. The growing period reaches over 210 days, up to 218 to 220 days on the coast. Such conditions favour the introduction of many ornamental trees and shrubs known for their sensitivity to winter frosts. There include:*Abies pinsapo*, *A. procera*, *Pinus pungens*, *Pseudolarix amabilis*, *Sciadopitys verticillata*, *Aralia elata*, *Castanea sativa*, *Paulownia tomentosa*, *Quercus imbricata*, and even such exotic plants as *Diospyros lotus* and *Sinarundinaria nitida* can be grown occasionally.

The transitory zone has harsher climate with up to 50 days seeing temperatures below 0°C. Precipitation is the lowest in Poland, often less than 500 mm of rain per year, which limits the cultivation of the more sensitive woody plants.

The eastern zone has a cold, more continental climate. There are over 50 days with temperatures below 0°C; the growing period is between 190 and 210 days, falling to only 160 days in the most extreme areas; and precipitation is 500 to 700 mm per year. Thus the only woody species which can grow there are adapted to long, cold, and windy winters, such as: *Acer negundo*, *Physocarpus opulifolius*, *Fraxinus americana*, *Aesculus hippocastanum*, *Potentilla fruticosa*, *Rhus typhina*, *Robinia pseudoacacia*, *Rosa rugosa*, *Sorbaria sorbifolia,* and *Tamarix gallica.*

The sub-Carpathian valleys and the Silesian lowlands of the submontane zone belong to the warmest region in Poland. The growing period lasts over 220 days, and precipitation is 600 to 800 mm per year. It is also the sunniest part of Poland so many valuable ornamental trees and shrubs can be introduced. Here you can find the old specimen trees of *Acer palmatum*, *Magnolia*, *Catalpa*, *Celtis*, and shrubs such as *Deutzia scabra* and *Weigela*.

The montane zone covers the lower reaches of Sudetes and Carpathian mountains. Abundant precipitation, up to 800 to 1,000 mm and the effect of montane oceanity compensate for the lack of warmth. There are 60 to 80 days with frost and the growing period is 190 to 210 days. As a result, successful cultivation of various species, including some evergreens such as *Rhododendron*, *Pieris,* and *Chamaecyparis* is possible.

HISTORY OF ORNAMENTAL PLANT CULTIVATION IN POLAND

The great increase in interest in the introduction of new ornamental trees and shrubs began at the start of the 19th century. The dendrological collections of Tytus and Jan Dzialynski in Kornik, near Poznan, is one of the oldest and greatest in Poland. A full list of these early introductions is published in the yearbook of the

Kornik Arboretum (Arboretum Kornik vol. XVI, XVII, XVIII, XIX). At present the number of woody plant taxa amounts to about 2,500 there. There are also interesting collections of rhododendron species and cultivars at Wojslawice, with many cultivars selected by Seidel. They are very hardy and well adapted to our kind of climate. The arboretum in Glinna has many exotic trees from milder climates, for example *Sequoiadendron giganteum*, while the forest arboretum in Rogow has experimental plots of timber trees and a very wide *Acer* collection.

Based on these collections, commercial nurseries developed. One of the oldest, Podzamcze, began as early as 1800. By 1914 this nursery covered 125 ha and produced 265 species of conifers, 961 broadleaf trees and shrubs, and 225 cultivars of fruit trees. The plantings in old parks give us the evidence of this very wide assortment in the older nurseries.

World War II stopped the development of the ornamental nurseries dramatically. The years after the war were not favourable. Ornamental trees and shrubs were considered luxury products so the traditional family type nurseries were closed or severely limited. New, big municipal or state nurseries propagated easy and fast-growing plants, such as *Salix*, *Populus*, *Acer negundo,* and *Robinia pseudoacacia*, needed for quick effects in green areas within towns under reconstruction. With time, the situation changed. Nowadays there are nurseries producing many species and modern cultivars. Their range is governed by consumers, mainly amateur home gardeners and the export firms. Consequently, nurseries produce great volumes of shrubs such as *Spiraea*, *Potentilla*, *Cornus*, and *Sambucus* for export mainly to Scandinavian countries; or the variegated blue and gold conifer cultivars, very much in fashion amongst amateur gardeners in Poland.

The following cultivars were introduced to commercial nurseries in recent years:

1979. *Juniperus horizontalis* 'Andorra'; *J.* × *media* 'Mint Julep', 'Gold Star'; *Picea abies* 'Frohburg'; *P. glauca* 'Echiniformis'; *P. omorika* 'Nana'; *Pinus mugo* 'Hesse', 'Humpy', 'Gnom', 'Wintergold'; *P. parviflora* 'Gimborn's Ideal', 'Templehof'; *P. sylvestris* 'Globosa Viridis', 'Watereri'; *Taxus baccata* 'Semperaurea', 'Summergold'; *T.* × *media* 'Straight Hedge', 'Stricta'; *Thuja occidentalis* 'Danica', 'Europe Gold', 'Smaragd'.

1981. *Chamaecyparis lawsoniana* 'Rijnhof', 'Alumigold'; *C. nootkatensis* 'Tatra'; *J. davurica* 'Expansa Variegata'; *J. media* 'Blue and Gold'.

1983. *Chamaecyparis lawsoniana* 'Kelleriis Gold'; *J. squamata* 'Holger'; *T. baccata* 'Schwarzgrüen'; *T.* × *media* 'Green Mountain'.

1986. *Chamaecyparis lawsoniana* 'Nidiformis', 'Gimbury Blue' = 'Gimbornii'?; *J. chinensis* 'Iowa'; *J. communis* 'Minima', 'Vase'; *J. horizontalis* 'Jade River'; *J.* × *media* 'Gold Coast', 'Mathot', 'Mordigen Gold'; *P. sylvestris* 'Fastigiata'; *T. occidentalis* 'Meckii', 'Sunkist', 'Tiny Tim'; *T. orientalis* 'Aurea Nana'; *P. mugo* 'Tyller'; *P. heldreichii* 'Schmidtii'.

1987. *Juniperus chinensis* 'Blue Alps', 'Filborn', 'Maney'; *J. communis* 'Gold Cone'; *J. horizontalis* 'Blue Chip', 'Blue Forest', 'Emerald Spreader', 'Grey Pearl', 'Hughes'; *J. sabina* 'Arcadia', 'Buffalo', 'Rockery Gem'; *T. baccata* 'Melford'; *T. occidentalis* 'Stolwijk', 'Gold Pearl'.

1989. *Picea pungens* 'Montgomery', 'Spek'.

SOURCES OF NEW PLANTS

Nowadays nursery production is developing and the interest in new species and forms is also increasing. Conifers are still the most popular but flowering shrubs and groundcovers are getting more and more attention. Street trees will be in demand in the future. What are the sources of new plants for Poland?

The easiest way is to import new cultivars from abroad but not all are hardy enough for the Polish climate. However, nurserymen like to have cultivars that are easy to propagate, fast-growing, and easy to sell. This has resulted, for instance, in the appearance of many cultivars of *Chamaecyparis lawsoniana* in our nurseries and a lack of grafted, dwarf cultivars of *Tsuga* and *Pinus*.

The second source is arboreta and botanic gardens. Unfortunately these research institutions do not have the interest or resources to promote their selected forms. For example, the Forest Arboretum in Rogow has such nice plants as our native *Daphne cneorum*, *Stewartia pseudocamellia* and *S. monadelpha*, *Cornus kousa*, *Halesia monticola*, *Acer griseum*, *A. tegmentosum*, *Podocarpus nivalis* from New Zealand, and unusual forms such as *Quercus rubra* 'Aurea', *Daphne mezereum* f. *alba*, *Sambucus racemosa* 'Laciniata', and *A. cappadocicum* 'Aureum'. At Warsaw Botanic Garden there are interesting selection projects for *P. mugo*, *J. horizontalis*, and *Taxus*. The *P. mugo* seeds were collected from natural stands in the Tatra Mountains. After 20 years the seedling population shows great diversity with the height of plants varying from 20 cm to 2 m. Of course, habit and foliage are very different, too.

We can not forget the standard assortment of shrubs for mass plantings. At the Research Institute of Pomology and Floriculture in Skierniewice we have started the clonal selection of some coniferous and broadleaved shrubs. In the case of *J. communis*, we have collected 68 clones of upright form, presumably 'Hibernica' or 'Suecica' from Polish nurseries. There are important differences in the stiffness of young shoots resulting in differences in habit of the older plants.

The second object of our work is *Ligustrum vulgare*. This plant is propagated in Polish nurseries mainly from hardwood cuttings and usually the plant material is not genetically defined. From 45 clones of this species we have found one of dwarf habit but we are not ready yet to say how much this form differs from the known cultivar 'Lodense'.

New Cultivars of Ornamental Trees and Shrubs from Poland

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Many valuable cultivars of ornamental trees and shrubs have been selected and propagated in Poland during last 100 years. Very few of them are mentioned in the international literature and known outside Poland. Many are valuable and worth popularising, especially because plants obtained from our climatic conditions can better withstand lower temperatures.

About 60 cultivars were bred by F. Rozanski at Podzamcze nurseries between 1896 to 1914, and over 200 new cultivars were bred and selected by A. Wróblewski at the time of his activity in Kornik, between 1926 and 1944. Unfortunately most of their cultivars were lost from cultivation. Their work was continued by many others including many interesting and valuable cultivars of: *Syringa vulgaris* (M. Karpow-Lipski), *Rosa* (L.Grabczewski and S. Zyla), and *Clematis* (S. Franczak and W. Noll). Of these, it is only some of the clematis cultivars that are propagated on a commercial scale outside Poland. I have found the following cultivars to be particularly beautiful and valuable for cultivation.

CONIFERS

***Juniperus communis* 'Anna Maria'** (J. Grabczewski). Sport of *J. communis* 'Repanda'; very slow growth, after 10 years to 30 cm wide and 20 cm high; branches upright, dense, needles grey-green; very good for small gardens, rock or heather gardens.

***Juniperus horizontalis* 'Agnieszka'** (J. Grabczewski, 1971). Seedling of *J. horizontalis* 'Glauca'; low spreading shrub with horizontal branches; growth similar to *J. sabina* 'Tamariscifolia', leaves only as needles, silver-blue.

***Larix decidua* 'Kornik'** (T. Bojarczuk, 1967). Propagated from a witches broom; slow growing low shrub with a globular habit and dense shoots.

***Taxus* × *media* 'Wojtek'** (W. Seneta, 1972). Seedling of *T.* × *media* 'Hicksii'; a semi-strong growth, narrow column; male form; foliage dark green; very good frost resistance.

***Taxus* × *media* 'Prof. Gorczynski'** (A. Marczewski, 1991). It is a seedling of *T.* × *media* 'Hicksii'; strong growth, very narrow, columnar; male form; strong frost resistance.

***Thuja occidentalis* 'Aurescens'** (A. Wroblewski, 1932). Seedling of *T. occidentalis* 'Lutea'; compact, narrow conical shrub to 5 m, golden-yellow foliage.

***Thuja occidentalis* 'Hoseri'** (A. Wroblewski, 1927). Seedling of *T. occidentalis* 'Globosa'; low growing shrub, of a regular globose form to 70 cm, branches densely set, fan-shaped.

***Thuja plicata* 'Kornik'** (J. Krol, 1964). It is a seedling of *T. plicata;* a narrow conical shrub, of medium-strong growth, with yellow foliage; high frost resistance.

DECIDUOUS TREES

***Fraxinus pennsylvanica* 'Crispa'** (F. Rozynski, 1905). Global, compact, dense crown; leaves wrinkled, dark green; good as a street tree.

***Malus × purpurea* 'Kobendza'** (A. Wroblewski, 1926-1938). Rich blossom mid May; flowers on long petioles, carmine-purple, with pink centers; fruit small, purple-red.

***Malus × purpurea* 'Makowiecki'** (A. Wroblewski, 1926-1938). Strong-growing tree with wide, dense crown; rich blossom end of May; flowers dark purple; fruit small dark purple, shiny.

***Malus × purpurea* 'Ola'** (J. Grabczewski, 1988). Semi-strong growing tree with broad crown and weeping shoots; mauve flower; fruit medium size, red and shiny, held on the tree up to December; resistant to scab.

***Malus × purpurea* 'Oltarzew'**. Strong-growing tree, with regular, dense crown; flowers pure white; fruit medium sized, yellow-gold; resistant to scab.

***Robinia pseudoacacia* 'Rozynskiana'** (F. Rozynski, 1896). Strong-growing, medium-size tree, branches dropping at tips; leaves large (up to 50 cm long) drooping; flowers in long, loose racemes, early and rich blossom; very pretty.

***Tilia tomentosa* 'Varsaviensis'** (J. Wrzesinski, 1926). Regular, conical, dense crown, with the leader shoot in the middle; leaves dark green above, grey tomentose beneath but hairs are not as dense and long as the species; very good street tree resistant to drought and air pollution, keeps green leaves longer than other limes.

SHRUBS

***Cotoneaster* 'Ursynów'** (W. Seneta, 1958). Probably seedling of *C. conspicuus* 'Decorus' × *C. dammeri*. Evergreen shrub with strong arching branches, wide-spreading; flowers white, covering whole plant, early summer; fruits bright red, persist well into the following year.

***Forsythia* 'Fontanna'** (B. Suszka, 1960). (*Forsythia ovata* × *F.* × *intermedia* 'Vitellina'). Strong growing up to 2.5 m; bearing large, broad-petaled, rich-yellow flowers in profusion; flower buds very frost resistance.

***Forsythia* 'Maluch'** (B. Suszka, 1960). (*Forsythia ovata* × *F.* × *intermedia).* Compact, slow growing with regular shape; small flowers densely placed on branches; very frost resistant.

***Syringa vulgaris* 'Chmurka'** (M. Karpow-Lipski, 1969). Small light-pink flowers in very big panicles.

***Syringa vulgaris* 'Kardynal'** (M. Karpow-Lipski ,1964). Small shrub; very big single flowers, black-purple flower bud, after opening dark violet purple; one of the nicest dark flowered cultivars; late blooming.

***Syringa vulgaris* 'Stefan Makowiecki'** (M. Karpow-Lipski, 1958). Large-size shrub; very big single flowers with rounded, open petals, flower buds dark purple opening to dark mauve.

ROSES

***Rosa* 'Camping'** (L. Grabczewski, 1966). Polyantha. Abundant small flowers of deep lavender-pink with pale specks; disease and frost resistant; excellent for borders.

***Rosa* 'Chopin'** (S. Zyla, 1980). H.T. Strong bush; flowers large, creamy white, with light fragrance; leaves big, dark green, healthy, persist in good condition to the winter.

***Rosa* 'Jantar'** (L. Grabczewski, 1966). H.T. Strong straight bush; flower large, dark crimson, merging into even darker shades.

***Rosa* 'Venrosa'** (S. Zyla). Strong bush; flower large, amaranth-red, very fragrant.

***Rosa* 'Warszawa'** (L. Grabczewski, 1957). H.T. Bicolor with bright orange centre and golden-yellow outside; strong, dark green, shiny leaves; good for borders.

CLEMATIS

***Clematis* 'Blekitny Aniol'** (S. Franczak, 1990). Jackmanii group, height 2.5 to 4 m; flower 10 to 15 cm, white-blue, with ruffled sepals and green-yellow stamens, very rich flowering June to August.

***Clematis* 'Dominika'** (S. Franczak, 1992). Jackmanii group, height 2.5 to 4 m; flower 12 to 16 cm, light blue with rounded sepals, very rich flowering June to August.

***Clematis* 'Ewa Franczak'** (S. Franczak, 1988). Lanuginosa group, height 2 to 3 m; flower 15 to 20 cm, white with a touch of pink, flowering June to September.

***Clematis* 'General Sikorski'** (W. Noll, 1980), syn. 'Jadwiga Teresa' (S. Franczak 1988). Lanuginosa group, height 2 to 2.5 m, flower 15 to 20 cm, medium blue with crenulated edges and golden stamens, flowering June to September.

***Clematis* 'Jan Pawel II'** (S. Franczak, 1988). Patens group, height 4 to 5 m, flower 10 to 15 cm, creamy white with pink traces which become more distinctive in the late summer as a pink bar, flowering May to October.

***Clematis* 'Kacper'** (S. Franczak, 1988). Lanuginosa group, height 2.5 to 4 m; flower very large (20 to 25 cm), intense violet with crenulated sepals and violet stamens, flowers June to October.

***Clematis* 'Kardynal Wyszynski'** (S. Franczak, 1988). Jackmanii group, height 2.5 to 4 m; flower 15 to 20 cm, glowing crimson with brown stamens, flowering June to September.

***Clematis* 'Matka Siedliska'** (S. Franczak, 1990). Florida group, height 2.5 to 4 m; flower 12 to 18 m, white with dark-brown stamens, double during the first flowering and single during the May to June and then July to August.

***Clematis* 'Niobe'** (W. Noll, 1975). Jackmanii group, height 2 to 2.5 m. Flower 10 to 15 cm, deep ruby-red (the deepest red clematis) with golden stamens, flowers continuously June to September.

***Clematis* 'Warszawska Nike'** (S. Franczak, 1988). Jackmanii group, height 2.5 to 3.5 m, flower 15 to 20 cm, velvet violet with golden stamens, flowers June to October.

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Predicting Graft Incompatibility in Woody Plants

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We have developed a theory to explain and predict graft compatibility and incompatibility in woody angiosperms. This theory is based on the similarity of major peroxidase enzymes in the cambial tissue of stock and scion. Peroxidases mediate the production of lignins and adjacent stock and scion cells must produce similar lignins, and have identical peroxidase enzyme patterns, to ensure the development of a functional vascular system across the graft union. In some species, all, or most, individual plants produce identical peroxidase patterns, and nurserymen seldom encounter problems of graft incompatibility. In species which have traditionally been problem grafters, we have generally found variability among individuals in peroxidase enzymes. Although detailed analyses of peroxidases in such species would be the ideal method for predicting graft incompatibility, there are some steps that the practical nurseryman can take to increase grafting success.

INTRODUCTION

The grafting of fruit trees began in Biblical times and is still an accepted method of propagation of selected cultivars. Numerous scientific papers dealing with graft compatibility and incompatibility have been published and, while we still have not established biochemical or physiological criteria to predict the outcome of grafting procedures, the "trial and error" research of the past has, at least, established guidelines and expectations that fruit growers have learned to accept. Grafting research with landscape trees has been negligible, and nurserymen are still producing potentially graft incompatible combinations even when the stock and scion belong to the same species.

The following discussion is based on a series of papers that began with an exposition of the bases of the theory that peroxidase enzymes in cambial tissue were important in determining graft incompatibility (Santamour, 1988a). This was followed by detailed analyses of intraspecific grafting problems in Chinese chestnut (*Castanea mollissima* Bl.), red oak (*Quercus rubra* L.), and red maple (*Acer rubrum* L.): Santamour (1988b, 1988c, 1989). These papers were preceded by extensive generic surveys of the peroxidase enzyme patterns in 64 taxa of *Acer* (Santamour, 1982), 90 taxa of *Quercus* (Santamour, 1983), and 10 taxa of *Castanea* (Santamour et al., 1986).

GRAFT INCOMPATIBILITY

Barbara Mosse (1962) has written that "the only certain criterion of incompatibility is the characteristic interruption in cambial and vascular continuity which leads to the spectacular smooth breaks at the point of union. At the point of union no normal vascular tissue develops. The gap thus formed is filled in by proliferating

ray tissue which does not lignify normally." Thus, the inability of a stock and scion to unite initially may not necessarily be a manifestation of graft incompatibility. Likewise, even if a grafted plant leaves a nursery with stock and scion "stuck together" it may still represent an incompatible combination. It may be impossible to come up with a definition of graft incompatibility that would satisfy all situations or all people. Therefore, in conversation or published papers it is important to explain the speaker's or writer's concept of graft incompatibility. In this paper, I consider long-term graft incompatibility to apply to situations where there is an initial "take" between stock and scion, but where poor growth of the scion or actual breakage at the graft union may occur after some years in the field.

ENZYMES AND LIGNIFICATION

All living plant tissues contain enzymes, special proteins that are essential catalysts for the chemical reactions leading to growth and development. Enzymes are the primary products of genes, and their analysis provides valuable data on the genetic distinctiveness of individual plants. Different tissues may contain different enzymes, and the same tissue may contain different enzymes at different stages of development. Peroxidase enzymes appear to have many diverse functions and they may be represented in any plant tissue by a number of different forms called isozymes. One exclusive function of the peroxidase isozymes is the formation of lignin(s). Lignin is the essential stabilizing component of the cell walls of woody plants. Although we often speak of "lignin" as if it were a single compound, the fact is that there are many lignins and they vary in chemical content between genera, species, and even between different tissues in an individual plant. Thus, no one can write a complete chemical formula for lignin. While it is true that the bulk of the lignin in plant cells is deposited in secondary cell walls to "strengthen" the cells, other parts of the cell, notably the middle lamella, contain appreciable quantities of lignin. Our theory of graft incompatibility (Santamour, 1988a) is based primarily on the inability of two adjacent cells with different peroxidase isoenzyme constitution to produce identical lignins in the middle lamella, thus leading to a disruption in normal cell-to-cell sap flow that will result in a non-functional vascular system.

INTRASPECIFIC GRAFTING

In developing our theory we have concentrated on certain species in which grafts between different plants of the same species could prove to be incompatible. Those species were, as noted above, Chinese chestnut, red oak, and red maple. Cambial tissue of individuals of these species varied in the production of two or three major peroxidase isozyme bands. These bands were designated, depending on their movement on the electrophoresis gels, as A, B, and C. In the most variable species we studied (red oak), all possible enzyme combinations were found among 463 different trees (A, B, C, AB, AC, or ABC), with the majority being A, B, or AB types. Only those stock and scion combinations with identical enzyme patterns were compatible (e.g. A on A, AB on AB) whereas non-identical combinations (e.g. A on AB, B on AB, AB on B) were incompatible. Similar results were obtained in intraspecific grafts of Chinese chestnut and red maple.

In some other species, notably Norway maple (*Acer platanoides* L.), sugar maple (*A. saccharum* Marsh.) and honeylocust (*Gleditsia triacanthos* L.), nurserymen and

growers had never reported any great problems of graft incompatibility—and we did not find any major variations in isoperoxidase banding patterns. Thus, there appears to be a strong correlation between peroxidase variability and potential graft incompatibility. Limited work on enzyme variation in European beech (*Fagus sylvatica* L.), Goldenrain tree (*Koelreuteria paniculata* Laxm.), sycamore maple (*A. pseudoplatanus* L.), and some ashes (*Fraxinus* spp.), indicated that intraspecific grafting could lead to graft incompatibility problems.

INTERSPECIFIC AND INTERGENERIC GRAFTING

Many fruit trees, and other trees, are commonly propagated an rootstocks of different species or even different genera, and we purposely avoided the investigation of such graft combinations so that we were faced with a minimum of genetic variability in the development of our hypotheses. Among the three major genera studied (*Acer*, *Castanea*, *Quercus*), the species of *Acer* and *Quercus* exhibited considerable variability in peroxidase isozyme patterns that could be somewhat related to subgeneric or sectional botanical classification. In *Castanea*, however, individuals of all 10 species contained only the same major peroxidase isozyme bands (A,B,C), alone or in combination. In this genus, therefore, we found that graft incompatibilities between species as well as interspecific hybrids followed the same "rules" as intraspecific grafts in Chinese chestnut. Anagnostakis (1991) showed that the genes responsible for the different peroxidase bands in several chestnut species were allelic and inherited codominantly.

VIRUS-INDUCED GRAFT FAILURES

In recent years, it has been found that certain cases of "delayed graft incompatibility" do not truly represent incompatible stock-scion combinations, but are caused by viruses that pass through the stock or scion and kill the cells of one of the grafting partners at the graft union. Such situations in apple, prune, oak, and walnut are more fully discussed, and references given, in Santamour (1988a, 1988c).

HINTS FOR PROPAGATORS

What can the practical propagator do with this theory? Some suggestions are contained in papers by the author (Santamour, 1988b, 1988c, 1989) for certain species. Ideally, all stock and scion plants should be enzyme-typed before grafting, but it is unlikely that any nurserymen, and few scientists, have the equipment and time for such an undertaking. One recommendation would be to collect seed for rootstocks of a particular cultivar from that cultivar. This procedure will greatly increase the chances that a high percentage of the seedlings will have peroxidase enzyme patterns identical to that of the cultivar, but because of the unpredictability of the male parents of the seedlings, there is no guarantee of higher levels of graft compatibility. A second possibility would be to develop seed orchards composed only of enzyme-typed clones or seedlings which, with normal cross-pollination, would produce seedlings with known enzyme constitution. Such procedures may be time-consuming, and microprogagation techniques would eliminate any potential grafting problems. Still, when rootstocks with desirable characteristics such as resistance to wilt diseases or nematodes are available, grafting and the solution of incompatibility problems may be the best method of developing superior trees.

DISCUSSION

Although we believe that our new theory of graft incompatibility represents an important step in the understanding of the grafting process, it does not explain all cases of graft incompatibility.

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Careroot Cell-Grown Liners and Understocks From Seed

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Expertrees is the marketing and sales organisation for four production nurseries in the southwest of Holland. This marketing set up has been in operation since 1990. The range of products we produce includes one- and two-year seedlings, transplant whips, and indigenous trees. Each production nursery has its own product speciality to help provide a comprehensive range of products. For decades we have been specialising in growing understocks and a wide choice of liners. "Small is beautiful" does not just apply to the plants but to the business units also. In addition, we encourage smaller growers to produce plants for us on contract. This helps us to remain competitive and contract growing is also the easiest way to keep quality levels high. Fellow growers from Holstein in northern Germany envy us for our quality, which makes Zundert special.

The production unit I will discuss in this paper is the one producing plug-grown plants. U.S.A. and Canadian propagators have utilized this production system for decades. Weyerhauser, a multinational forestry company, has been producing billions of Douglas fir this way and they even had a subsidiary in Europe.

Until recently plug growing was predominantly used for forestry seedling production. There are several systems on the market, each having its own specification. However, the principles underlying all systems are: plug cells with open bottoms for air pruning and cell walls with vertical ridges for directing root growth down and preventing spiraling.

The Swedish company Hilleshög has developed a system based on the principal called HIKO, which they have introduced in France, Spain, Ireland, and Austria. In the United Kingdom the Rootrainer that originated from Canada is well known. Austria has developed its LICO system for producing forestry seedlings.

The Careroot System as we use it today was developed by Mr. Andy Domen in response to a growing demand for containerised stock, both in forestry and in ornamental plants. It took about 6 years to get to its present state of development. We use five different types of trays, three in polystyrene and two in hard plastic, having the following sizes (in cm):

Type	Depth	Width at top	Width at bottom
P204	7.5	2.5	1.8
P84	7.5	4.5	4.0
P40	9.5	6.7	4.0
P96	7.5	3.4	2.2
P35	11.5	4.5	3.3

The P204 is used mainly for conifer seedlings and small-leaved, hardwood seedlings. The bulk of the P204 production is used by us as lining-out material for

forestry field growing, e.g. *Picea*, *Pinus*, *Pseudotsuga*, etc. We save a year on production with this system.

The P84 is mainly used for ornamental liners and rootstocks, some of which have a caliper ready for grafting.

The P40 is used for graftable understocks and bushier liners. The P40 is roughly the equivalent of a 7-cm pot liner. We do not sow directly into the P40, but we transplant into it with P204-grown plants.

The P96 is used predominantly for broadleaved seedlings to be transplanted into the open ground to make a transplanted seedling within 1 to 1½ years.

The P35 is used mainly for big-leaved hardwood understocks, e.g. *Aesculus*, *Castanea*, etc.

The main differences between Careroot plants and most other cell-grown plants are: the wide choice of ornamental species, and the grading (we do not supply plants in the trays but take them out and grade them) to meet customer specifications as much as possible.

The main features of Careroot plants are:

- Better take of liners because of root protection.
- The spiraling of roots is minimised.
- Plants begin growth immediately in the 1st growing season.
- Plants build a finer root system that spreads out more evenly.
- More efficient production planning with year-round production and handling.
- Plants are well hardened off which is particularly important for understocks.
- They store well in cold storage.
- Plants are graded through manually to meet customers specifications.
- Plants are packed in plastic crates and are relatively cheap to handle and transport.
- High level of seed technology allows us to grow more difficult species successfully.

The best results are achieved with cell-grown material that has been in the plug for as short a period of time as possible. Vital to the whole system is that the plug is properly rooted through. A root/shoot ratio with more root than shoot is best. Also, the finer the roots are the better a plant will take and grow.

We can say that, provided they are used in the right way, at the right time, etc., cell-grown material performs better than bareroot material generally speaking. We also think there is a great future for cell-grown material in general, but there will obviously always be enough room for field-grown material in the market and we want to keep it like that too.

Progress in Controlling Disease in Hardy Nursery Stock

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INTRODUCTION

Modern nursery techniques combined with market requirements for quality in quantity have created growing conditions which favour development of epidemic disease. This has been exacerbated by restrictions in pesticide usage and an associated decline in the availability of effective fungicides. This paper outlines three new developments in alternative disease control and illustrates the radical changes in disease management which will be essential for growers in the 1990s.

ALTERNATIVE DISEASE CONTROL METHODS

Biological Control. Biological control agents (BCAs) offer a natural, environmentally-friendly means of controlling disease. In 1991, Grace Sierra began to test market GL 21 in the U.S.A. This product, based on the fungus *Gliocladium virens* and formulated as an easy-to-use prill, shows considerable activity against the damping-off fungi *Rhizoctonia* and *Pythium* (Lumsden and Locke, 1989).

Previous attempts to introduce BCAs into practical use have often been frustrated by difficulties in establishing stable populations of the organisms in the growing medium. Lumsden and Locke (1989) found that *G. virens* remained effective over a period of at least 60 days.

In comparative tests with the fungicide PCNB (quintozene) the control of *Rhizoctonia* stem rot of antirrhinum usually was as good as, if not better than, that achieved with the chemical (Locke et al., 1988).

The performance of GL 21 was not affected by a range of fungicides or insecticides applied before the introduction of the BCA. The fungus is active over a range of conditions but declines above pH 7.9 and where the compost remains wet for long periods of time.

Polymer-Forming Films. There are available several products which, when sprayed onto plants, form a thin flexible anti-transpirant film. These are based mainly on terpenic polymers and products include Vapor Gard, Nu Film P, and Emerald.

At SAC Auchincruive, anti-transpirant films are being evaluated for their potential in disease prevention. Used at the propagation stage, they offer the interesting possibility of reducing transpiration stress without recourse to polythene covers or mist. By reducing the relative humidity around the cuttings the opportunity for the growth of pathogens such as *Rhizoctonia* and *Botrytis* should be drastically reduced. In trials with *Rhizoctonia*, the foliage of all cuttings of *Erica cinerea* 'Alba Major' and *Weigela florida* 'Foliis Purpureis', placed under polythene and inoculated with the fungus two weeks after striking, were dead when assessed 2 weeks later. In contrast, when cuttings were treated with 5% Vapor Gard pre-inoculation none of the cuttings died and only 20% of heath and 30% of weigela

cuttings suffered minor foliar damage. Rooting of weigela was relatively unaffected by a low humidity environment, but rooting of heath was more variable than under polythene.

Tests in established plants so far have been concerned with agricultural crops, but the protectant principles apply equally to hardy nursery stock. A reduction in powdery mildew on barley of 94% compared to untreated and an 83% reduction in brown rust of broad beans using a 2% spray of Vapor Gard illustrates the very effective disease prevention possible using antitranspirant films.

Disease Diagnosis Kits. Stem-base and root problems are a major cause of concern for all HNS growers. Faced with wilting or dying plants urgent action is needed. However, obtaining a diagnosis using standard plant clinic procedures takes so long that by the time a result is obtained the crop may have been consigned to the skip.

For a number of years, attempts have been made to improve pathogen diagnosis using serological techniques. Kits for the detection of virus diseases have been available for some time, but it is only recently that it has been possible to identify fungi using this technology. The kits, detecting *Phytophthora*, *Pythium,* and *Rhizoctonia*, were introduced in the U.S.A. in the late 1980s by Agri-Diagnostics Associates. They are available not only in the standard multiwell plate format, but as unique on-site detectors. These are designed for use by growers and provide results in a remarkable 10 minutes.

McDonald et al. (1990) compared the detection of root pathogens on ornamentals in California using the multiwell kits and standard culture plate techniques. Overall, there was an encouraging degree of correlation between the two methods. A number of samples gave marginal positive results with serological tests, but proved negative by culture plate. This could be related to samples collected from a nursery routinely drenching with metalaxyl and highlights a major problem with culture plate techniques in trying to isolate fungi from fungicide-treated plants. In just a few cases the kits did not detect a pathogen whereas culture plating did. This could have been influenced by the procedure used in selecting tissue for the test.

According to McDonald et al., (1990) the accuracy of the multiwell kits is estimated at 75% when the proportion of diseased to healthy tissue is 0.4%, rising to 95% when the proportion of disease tissue is 1%. Benson (1992) found that both the multiwell and on-site kit formats could reliably detect *Rhizoctonia* on stems of poinsettia cuttings when the lesions were only 1 mm long.

A potentially very valuable application of the kits is in monitoring re-circulating irrigation water for propagules of *Pythium* and *Pythophthora*. As the test kit result is quantitative as well as qualitative, it is possible to detect the build-up of pathogens in water. This promotes the timely application of the first and repeat fungicide treatments and avoids unnecessary pesticide usage (Ali-Shtayeh et al., 1991).

DISCUSSION

There can be no doubt that, for both economic and environmental reasons, the coming years will see radical changes to crop protection in horticulture. Effective disease control will require growers to adopt integrated pest management programmes based on a better understanding of the pathogens and the application

of new technologies. The three areas discussed in this paper are good examples of innovative approaches which already are at, or close to, practical application.

GL 21 promises to be one of the first effective BCA products against important damping-off fungi. It meets environmental requirements and appears not to have the phytotoxic disadvantages which the commonly used fungicides have been shown to cause at the rooting stage of many nursery stock subjects (Holmes and Litterick, 1990). Anti-transpirant films offer considerable advantages over conventional fungicides. They are broad spectrum in activity, simplify crop protection management decisions, are safe for operators, environmentally friendly, and reduce transplant shock. Diagnostic kits offer a revolution in the detection and management of root and stem-base pathogens. Early and accurate corrective action will reduce losses and avoid unnecessary pesticide usage. Importantly, they will enable growers to identify the 50% of situations where root problems are of a non-pathogenic origin. Over the next few years it can be anticipated that a much wider range of kits will be available to growers, not only for the diagnosis of pathogens but for monitoring pesticide residues, resistance of pests to pesticides, etc.

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New Plants from Hungary Tolerating Urban Conditions

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Selection of woody ornamentals to tolerate environmental stress has been carried out in Hungary for over 30 years. This paper gives descriptions of some recently named clones and new cultivars.

INTRODUCTION

As a result of its geographic position, Hungary lends itself to selection of woody plants which tolerate environmental stresses. The summer is warm with temperatures reaching a maximum of 30 to 35°C, and the winter is cold and irregular with temperatures sometimes falling to between -26° and -30°C. Yearly rainfall varies between 380 and 820 mm and comes mostly in the autumn and winter. These extremes are multiplied on the poor sandy and saline soils of the Great Hungarian Plains, on the dry limestones and dolomites of low mountains, and in the dry, warm and polluted atmosphere of cities and towns.

Selection of woody ornamentals for such conditions started in the early 1950s by the Department of Horticulture and Dendrology of the University of Horticulture and Food Industry. The first results were three cultivars of *Tilia tomentosa* and seven cultivars of *Sorbus* species.

At present, the work is carried on at several establishments: University of Horticulture and Food Industry, Budapest; PRENOR—Landscaping Enterprise and Nursery, Szombathely; SASAD Cooperative Nursery, Budapest; Barabits and Sons Nursery, Sopron; FÖKERT Municipal Nursery of Budapest, Tahi; and Municipal Gardening Enterprise, Pécs.

DESCRIPTIONS OF CULTIVARS

As a result of increased selection work, many new hardy cultivars and named clones have been introduced in the past 10 years. The most important of which are listed below.

***Ailanthus altissima* 'Purple Dragon'**. *Ailanthus altissima* is the hardiest urban tree in Hungary; it tolerates drought and bad soils extremely well and grows like a weed in polluted environments. This clone is a female form found in Budapest. It has a straight leader, fast growth, and a regular rounded crown becoming flattened with age. The dark-purple, winged fruits are born in abundant clusters and retain their intensive colour from July through August and early September. Foliage is shiny green with red petioles and leaflet veins, and shoots purplish brown. Propagation: bench grafting in late winter, micropropagation, or root cuttings from micropropagated plants.

***Fraxinus ornus* 'Mecsek'**. Bearing the name of the mountain it originates from, 'Mecsek' is probably the finest globular form of *Fraxinus* ever selected in Europe. The crown is a perfect globe with a dark green foliage and crowded stout branches (ultimate crown diameter 3.5 to 4 m). White flowers open in May. Propagation: top-working (budding or grafting) on *F. ornus* or *F. pennsylvanica*.

***Prunus* 'Balaton'**. A narrow columnar form reaching an ultimate height of 5 to 6 m and a width no more than 1 to 1.5 m; rich blossoms of pink-eyed white flowers open February to March; healthy foliage and large sweet nuts in September characterize this cultivar. Propagation: budding in late August onto wild almond seedlings.

***Prunus laurocerasus* 'Piri'**. A compact semi-globe reaching an ultimate height of 0.6 to 1.0 m and a diameter of 1.0 to 1.4 m with leaves leathery, obovate, dark green in color, 3 to 6 cm long and 2 to 3 cm wide. Suitable for small gardens or as a ground cover and has a much better winter hardiness than *P. laurocerasus* 'Otto Luyken' in Hungary. Can tolerate 20 to 25°C below freezing without damage.

***Prunus laurocerasus* 'Mari'**. A wide shrub with upright branches reaching a height of 1.5 to 2 m. Leaves are leathery, dark glossy green, 6 to 8 cm long and 3 to 5 cm wide. Like *P. laurocerasus* 'Piri' survived winter temperatures 20 to 25°C below freezing with little or no damage. Both cultivars were bred by Dr. M. Józsa in Szombathely. Propagation: easy from semi-ripe leafy cuttings in August to September.

***Ribes alpinum* 'Soroksár'**. A fast-growing male form, with erect and later overhanging branches which produces a flattened and wider bush then *R. alpinum* 'Schmidt'. Ultimate height is 1.0 to 1.4 m with a diameter up to 2.5 to 3 m. Leaves are small, dark glossy green and resistant to diseases. Excellent ground cover for shade and sun, and along highways. Propagation: softwood cuttings in June.

***Salix* 'Golden Spiral'**. A fast growing corkscrew-willow, probably a spontaneous hybrid between *S. matsudana* 'Tortuosa' and *S. alba* 'Tristis'. It was found as a seedling near lake Velencei. Shoots, twigs, and branches are much contorted, light yellow in the summer, turning rich golden orange in the winter. Propagation: hardwood, softwood, or semi-ripe cuttings almost any time of the year.

***Sorbus aria* 'Favorit'**. A wide columnar form, rounded at the base and pointed and rounded towards the top. Ultimate height is 6 to 9 m, with a diameter of 2.5 to 3 m. Leaves are leathery obovate or leaves, 14 to 18 cm long and 7 to 8 cm wide, glossy green above and white tomentose beneath. Autumn colour is yellow, and fruits are downy and red. Propagation: budding in August onto *S. intermedia* or other *Sorbus* rootstocks.

***Tilia tomentosa* 'Bori'**. A small tree with a flattened globular crown no more than 4 m in diameter after 16 years. Leaves are relatively small, dull green above and silvery tomentose beneath, completely resistant to red mites, and free from fungus diseases. Propagation: top-working (budding) in August onto *T. tomentosa* or *T. platyphyllos* seedlings.

***Tilia tomentosa* 'Gray Pillar'**. A large tree with upright branches having a compact columnar form when young and becoming wider pyramidal at maturity. Leaves are leathery, dull green above and silvery grey beneath. It is resistant to red mites and free from fungus diseases. This was the fastest grower in the nursery among 38 selected clones and makes a completely straight upright stem without any staking. Propagation: budding in August, or bench grafting in February to March, on *T. tomentosa* or *T. platyphyllos* seedlings.

Introducing and Promoting British Columbia's Native Plants for the Urban Landscape

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British Columbia has a rich flora of native plants because of its varied climatic regions—the very high rainfall of the Queen Charlotte Islands, the drier climate of eastern Vancouver Island and the adjacent Gulf Islands, the cold alpine areas of the many mountain ranges, and the arid regions of the province's interior Okanagan Valley.

The University of British Columbia Botanical Garden Plant Introduction Scheme (PISBG) has now resulted in the public release of 14 new cultivars, with over 5 million plants having been produced through the programme. Four of these plants are native selections: *Arctostaphylos uva-ursi* 'Vancouver Jade', *Ribes sanguineum* 'White Icicle', *Potentilla fruticosa* 'Yellow Gem', and *Penstemon fruticosus* 'Purple Haze'. With the cooperation of the BC Nursery Trades Association and the BC Society of Landscape Architects, these plants have been well promoted and have now largely found their niche in the market. *Arctostaphylos uva-ursi* 'Vancouver Jade' is now the most widely-grown ground cover in BC because of its ease of propagation, dense habit, attractive flowers, and diverse use in the landscape. *Potentilla fruticosa* 'Yellow Gem' has quickly caught on for retail and landscape sales; its advantages in Canada over existing cultivars are hardiness, compactness, and extended length of flowering time. The compact evergreen shrub, *Penstemon fruticosus* 'Purple Haze', has been well received by industry, with one of the first urban plantings being 3000 plants for a large residential development in suburban Vancouver. Sales of the white-flowering native currant, *Ribes sanguineum* 'White Icicle', have been disappointing so far. Shrubs that produce white flowers in early spring do not seem to sell well in BC, brighter colours are more popular. *Ribes sanguineum* is not a major crop in nurseries but we are confident this plant will be more popular in Europe.

As in many other countries, the use of native plants in the urban landscape is becoming more important. The reasons for this trend include environmental issues and native plants' adaptability for specific sites—for example, mine reclamation, revegetation, and stabilization projects. Nurseries that have specialized knowledge of forest seedling production have effectively integrated seed and deciduous hardwood cutting propagation of native plants into their production schedules. There is still considerable promotional work needed to encourage the retailer and home gardener to use native plants, particularly at peak sale time in spring with the competition from traditional colourful annuals and perennial plants.

Careful selection, evaluation, and commercial trials are vital with native plants for a variety of reasons:

- They can often be unsightly and inappropriate when brought into a landscape setting. This can result in invasiveness and poor habit. For example, a species from the dry interior region of the province may

become weedy or just die out under moist coastal conditions. The poor habit of a species may be less obvious in the wild.

- A native plant may have a short flowering season with small unattractive flowers, followed by dead seed heads and foliage that can also make plants unsightly.
- The species may develop considerable genetic variation, resulting in problems relating to quality from the nurseries and poor growth in the landscape.
- There may be inconsistency in propagation results.
- There may be cultural problems during nursery production, for example, poor response to conventional composts, nutrition, and overhead irrigation.
- The native plants may be too tall in containers and with poor flower colour at the time of marketing, thus giving an immediate negative impact to the retailer and consumer.

The potential for improved native plant selections has been a priority for the BC nursery and landscape industries. As a link with the Plant Introduction Scheme, the provincial and federal governments funded a three-year program to proceed with a systematic collection of native plants from different areas of the province. This work was carried out by K.W. Nicholls, research scientist for PISBG, and resulted in the collection of nearly 1000 specimens of vegetative material and seed. This germplasm, now at the Botanical Garden's nursery, will provide an important resource for selection, evaluation, and breeding.

Two more improved plants from the existing collections in the BC Native Garden component of the Botanical Garden, both of which show considerable genetic variation in the wild, have now been released to participating nurseries. *Vaccinium ovatum* 'Thunderbird' is relatively compact with outstanding reddish-coppery new growth and masses of pink flowers borne over a number of weeks. Clusters of black berries form during late summer. Another release is *Paxistima myrsinites* 'Emerald Cascade', a compact weeping form of myrtle boxwood or Oregon box. This hardy evergreen is particularly valuable for drier and colder locations.

An important partner in this program is the BC Ministry of Highways. They have provided useful advise and test sites, and, in turn, will be a major user of native plant introductions. The challenge will be to ensure that participating nurseries grow sufficient numbers for the large quantities the ministry will require. The types of plants they need in BC may be quite "ugly" in the garden setting or nursery production stage — BC Highways look for suckering, fast-growth, etc.

Taking a lesson from major nurseries, the Plant Introduction Scheme has made promotion and marketing a top priority. This has included exhibits at trade shows, media releases and interviews, colourful promotional sheets, and the design of custom-made labels to identify PISBG plants sold at retail outlets. Promoting the plants to landscape architects and contractors requires another direction. In addition to evaluation days to discuss trends for future years, a custom-designed folder will be produced for each landscape architect company in the province. This will contain the promotional sheets, cultural information on the plants' uses in the landscape, and names and addresses of suppliers.

Our experience in successfully introducing plants into the urban landscape can

be summarized by listing the following recommendations:

- Cooperate and liaise closely with the nursery and landscape industries. Ensure the final plant selections are made by landscapers and growers.
- Ensure effective evaluation with a strong emphasis on the plants' targeted markets.
- Thorough testing and evaluation, both under nursery conditions and in different landscape locations, of the plant's performance under the extremes of winter and summer temperatures. The programme currently has test sites across North America, although our experience has shown that it is not always possible to plan for every eventuality.
- Develop a strategy for promotion and marketing.
- Develop licensing agreements, where applicable, well before the plant is introduced. Pride of Place Plants (Blakedown, Worcestershire, UK) has signed a five-year agreement with the university to test and evaluate potential new plants for the European market.
- Choose easily identifiable cultivar names for mass marketing.
- Ensure there are sufficient plants in the system for introduction in future years.
- Keep abreast of future trends in the types of plants required for retail, wholesale, and landscape markets.
- Try to solve any problems that occur in the program immediately. Unnecessary delays can rapidly compound a problem.

A grant has been received recently from the BC Ministry of Agriculture under the "Applied Research Partnership" program in which matching funding is provided by the nursery industry, supported by the Henry M. Eddie Plant Development Foundation. The initial grant is for two years to fund a breeding program conducted by K.W. Nicholls, using mainly native plant material collected during the past few years. Plant breeding takes time, but it is important to take the long-term view as new plants must be on-line for future years. Once a new plant is developed, evaluated, and selected, the Botanical Garden's industry-advised marketing and promotion network will help to ensure it is quickly accepted in the industry and urban landscape.

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Breeding Woody Ornamentals in Sweden

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During the last 10 years, attempts have been made to improve the genetic quality of ornamental trees and shrubs cultivated in Swedish nurseries. Selections have been made in cultivated and wild collected plant material, as well as hybridisation work. The work has concentrated on finding hardy and healthy, narrow-crowned trees for the modern Swedish garden and low growing shrubs for parks and gardens as well as for ground covers. So far about 25 clones and 7 seed provenances have been introduced on the Swedish market and given a special quality symbol - E - which is printed on the plant labels.

INTRODUCTION

A lot of work has been carried out during the 1980s to improve the genetic quality of trees and shrubs produced in Swedish nurseries. This work has been carried out at three different locations and departments, all belonging to the Agricultural University. At Umea, lat. 64 degrees, the work has been concentrated on selection among genotypes of ornamental trees and shrubs that have been growing for several decades in parks and gardens in northern Sweden. At Uppsala, lat. 60 degrees, they have established and tested about 50 orchards for seed production of trees and shrubs. At Alnarp in southern Sweden, lat. 55 degrees, we have concentrated our work on selection of clones in cultivated and wild collected material and on hybridisation. The results presented in this paper are related to work carried out at Alnarp.

CURRENT PROJECTS

Crabapples. Many crabapple cultivars in general cultivation in Sweden have limitations compared to the optimum of the genus. Most of them are susceptible to apple scab and mildew. Some are too big for modern Swedish home gardens.

Ten years ago seed was collected from ten of the best cultivars of crabapples. The flowers were open pollinated and the pollen mixed between these ten parents. About 500 plants from each half sib family were then field planted, making a total of nearly 5,000 plants. Along with scab resistance and quality of flowering and fruiting, we have selected for compact, columnar, or weeping growth plus red coloured leaves.

Spiraea. In 1991 a project was started with the intention of finding good dwarf or compact growing spireas. The first selection has been made from an open pollinated cross with *S. japonica 'bumalda'* (30 cm by 120 cm in 30 years) as the mother with several of the new yellow *Spiraea* selections.

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[1] Paper presented at Conference by Kenneth Lorentzon.

Perennials. The increasing interest in perennials has now reached the point where a demand for domestic selections and evaluations has arisen. In co-operation with wholesale producers of perennials in Sweden we have begun to evaluate new cultivars; select plants from different wild collected material; select pulmonarias from open pollinated crosses with *Pulmonaria longifolia* as the mother; and develop some good white and red cultivars of *H. orientalis*.

Conservation. Together with the Swedish branch of the World Wide Fund for Nature (WWF) we have started a project on the conservation of valuable old garden plants that are now threatened. The most vulnerable plants are the short-lived ones such as perennials and bulbous plants. Another part of the project is to restore the old and hardy *Buxus* to Swedish trade.

INTRODUCTIONS.

During the last 12 years, 25 cultivars and five seed provenances of trees and shrubs have been distributed to Swedish nurseries. Some of them will be described below:

Aronia. *Aronia melanocarpa*, black chokeberry, is a shrub with natural distribution in eastern North America. It was introduced to Swedish cultivation some ten years ago. The types in cultivation are propagated from seed and are often considered too strong growing (2 to 2.5 metres in height) for parks and private gardens. The cultivar 'Hugin' was selected from populations propagated from wild-collected seed. It is a compact shrub reaching only one metre in height and is very floriferous. The autumn colouring is good.

Sorbus. Four new rowans have been introduced to the Swedish market.

Sorbus 'Astrid'. 'Astrid' is a medium-sized to small tree with a broad crown. The leaves are partly pinnate. The fruits are big and apricot pink.

Sorbus 'Brigitta'. 'Brigitta' is a medium-sized to small tree with a pyramidal crown. The leaves are rather big with a striking bluish-green colour. The fruits are butter yellow. This cultivar is supposed to be a hybrid between *S. commixta* and *S. aucuparia* 'Xanthocarpa' and seems to be much hardier in Sweden than the yellow-fruited Lombarts hybrids.

Sorbus 'Dodong'. 'Dodong' is a strong-growing rowan with big leaves and strong autumn colours, with remarkably large, many-flowered, corymbs and pear-shaped orange-red fruits. This cultivar was selected from a population of plants propagated from seed collected on the South Korean island of Ullung-do by the Swedish dendrologist Tor Nitzelius in 1976. So far it has not been possible to identify the species.

Sorbus 'Rosmari'. 'Rosmari' is a small- to medium-sized tree with an oval crown. The leaves are greyish green and develop pink autumn colours. The fruits are dark pink and the cultivar is an improvement to the Dutch cultivar 'Kirstén Pink'.

Two new whitebeams have also been introduced.

Sorbus aria 'Gigantea'. 'Gigantea' was selected by the Dutch dendrologist and nurseryman Lombarts. It has been tested in several places in Sweden. Its most valuable characteristics are the strong growth, large silvery leaves, and the rather narrow oval crown.

Sorbus incana. This is a rather compact growing whitebeam, new to cultivation. The species was described by Hedlund in 1901 from cultivated plants. It has a narrow crown with a strong leader. The foliage is dense and dark green with a

silvery shine in spring. The mature bark is smooth and silvery. A useful tree for streets and squares where space is limited.

Salix repens. This creeping willow has a wide distribution in southern Sweden where it occurs on heathlands, mires, and shores. Until recently there have been no really low-growing types of this willow in cultivation. In this project we have collected about 150 promising types from natural sites. From them, two male clones have been given cultivar names and they are now produced in Swedish nurseries. Although several female clones proved to have nice foliage and good growth performance they had to be discarded because of their unsightly seed production. When 100 plants with interesting growth and foliage were selected from plants originating from crossings, 96 proved to be female.

The two cultivars named are 'Green Carpet', with lustrous green foliage and 'Grey Carpet', with closely hairy, more greyish leaves. They will both grow to 15 to 25 cm in height and will cover one square meter in three to four years from planting.

Symphoricarpos. The common snowberry (*S. albus* var. *laevigatus*) has been used in Swedish gardens for centuries. It is normally 1 to 1.5 m high. *Symphoricarpos* 'Arvid' was selected from plant material propagated from seed, wild-collected in North America. In 8 years a plant will grow to 1.5 metre in width and 0.4 metre in height. So far it has not been possible to identify the species. This cultivar has great potential as a ground cover plant. It sets very few berries if it is not cross-pollinated by a nearby common snowberry.

Euonymus. *Euonymus europaeus* is indigenous to southern Sweden. The selection 'Evert' is from wild-collected seeds in that area. The shrub will, in time, reach 5 metres in height and distinguish itself by having bright red fruits. Compared to older cultivars like 'Aldenhamensis' and 'Red Cascade' and a long series of wild collected plants it has proved to be superior. Plants of 'Evert' show good disease resistance.

Forsythia. *Forsythia mandshurica* is a very rare shrub in cultivation as well as in the wild. It has only been wild-collected once in Manchuria in northern China. This forsythia has a rather different habit compared to others, the branches stand up stiffly, slightly suckering. Flower buds are blackish and prominent, and leaves colour up well in the autumn in tints of orange-yellow to deep wine red. The flowers are sulphur yellow, remarkably large and it is the first of the forsythias to flower in Sweden. The flowering is not as prolific as with other hybrid forsythias, but still impressive.

Philadelphus. *Philadelphus coronarius* 'Finn' is a new selection from the common mockorange complex where scent and the delicate chartreuse colour have been combined. The flower is slightly nodding.

***Populus* 'Beloni'**. This is a hybrid between *P. wilsonii* and *P. lasiocarpa*, made in 1974 in the Botanic Garden of Gothenburg, and was selected from just five plants. It has a strong pyramidal habit. 'Beloni' is a male clone, so there will be no problems with untidy seeds. The leaves are intermediate between the parents, 15 to 25 cm by 12 to 18 cm. Grafts of this poplar tend to have incompatibility problems and they should be micropropagated instead, or late summer cuttings taken.

This hybrid had been made in 1956 in Kornik, Poland, although we were not aware of it in 1974. Six clones have been kept of this cross.

SEED PROVENANCES

Alnus. Alders are widely used as pioneer trees. The two most popular have been *A. glutinosa* and *A. incana*, which both need to be thinned after only 5 to 8 years. This thinning is a cost that could be reduced by using some of the slow-growing shrub alders. *Alnus maximowiczii* from Japan and Sakhalin and *A. sinuata* from the west coast of North America have been the two best in our tests. These slow-growing pioneer trees do not need thinning as they will eventually be overtaken by the slower-starting broadleaves and slowly be shaded out.

On their own they are still worth growing for their early and long inflorescences, their large leaves and attractive winter buds, and their large "cones." *Alnus maximowiczii* has a very strong scent, similar to that of the smaller-leaved lepidote rhododendrons.

Both could very well be used as windbreaks, where 4 to 6 m of growth is sufficient.

Prunus grayana. *Prunus grayana* is a shrubby, Japanese bird cherry with elegant, vase-shaped form. The flowers are pendant in 12- to 20-cm racemes followed by 6- to 7-mm black fruits which contrast with the light-yellow autumn colours.

A New Rockwool Based Growing Medium for Container Plant Production

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Grodania A/S, in conjunction with progressive nursery stock growers in the UK, has developed a complete peat-free production system based on Grodan rockwool for container nursery stock. Grodan-media plants can be grown side by side with peat-media plants to similar quality standards. This means no modification of existing production systems.

Trials carried out under full commercial conditions have given comparable results to peat-based compost from propagation to liner pot and in the final 3 litre container. Indications are that fine tuning on the nursery will give improved results over peat. Assessed visually by nurserymen all plants were considered to be of marketable quality. From data recordings, there were little or no significant differences between the treatments. All plants received the standard peat treatments.

BACKGROUND

Work started on a Grodan compost in 1986 as a direct result of Danish pot plant growers' concerns about poor structural quality and uniformity in peat. Trials proved that pot plants would grow well in 100% Grodan rockwool but it was not free flowing, which caused handling problems and the project was abandoned. As part of routine re-evaluation the project was looked at again in early 1989. By 1990 a flowable rockwool medium, code named "Derek", had been developed. Derek has been designed to improve on some of the strengths of peat and avoid some of its weaknesses. It is a designed substrate from naturally occurring materials, produced in a precise and controlled way. This ensures continuity and uniformity and the ability to tailor-make substrates.

CHARACTERISTICS

In Denmark, research showed that pot plant growers wanted a weed-free, structurally stable medium, which would not shrink in the pot, and had the high air-holding capacity of a medium-light peat. In addition they wanted improved water-holding capacity and some buffering capacity. Derek was designed to fill all these needs (see Table 1). The benefits which the Danish growers identified could also be applied to UK nursery stock production.

AFP and Water-Holding Capacity. The starting point for any compost design is the water : air balance. The Grodan rockwool component of Derek is a specific mixture of special types of water repellent and water absorbent rockwool which, at field capacity, will give an air-filled porosity (AFP) of around 20% in the pot.

At this AFP level, Derek is able to hold 60 to 70% water. A peat with a similar water-holding capacity would be expected to have an AFP of about 10%. Water held in Derek is only loosely held, so the roots do not have to apply high suction pressure to get at it.

Table 1. Physical and chemical data.

Property	Units
Water-holding capacity	60 - 70% by volume
Air-filled porosity	20% by volume
pH	6.0 -6.2
Conductivity	0.1 - 0.2 mS/cm
Cation exchange capacity	25 - 30 meq/100 g
Weight	0.75 - 2.2 kg/ 3-litre pot
Colour	Develops to dark grey/black
Pest/disease/weed seeds	Guaranteed free

Observations indicate that the evaporation rate of water from Derek is exactly the same as from a wet peat surface. Even in the liner pot, the top surface will dry off in much the same way as a peat compost. Rewetting is easier than peat.

Weight. At field capacity Derek will weigh about 10 to 15% more than a peat compost. Generally, Derek will be used below field capacity. Transport time could easily be extended by topping up the water level.

Buffering Capacity, pH, and Conductivity. The buffering capacity is low enough to allow good nutritional control during crop production and high enough to enable feed to be held for normal shelf life requirements. Controlled-release fertilisers used at standard peat rates gave normal plant growth. Derek's pH is around 6.0 to 6.2 and does not need lime incorporation. Like peat its pH will be affected by the water supply used. Trials on nurseries with water pH levels of 7.4 and 7.6 have not adversely affected crop growth rates.

The conductivity of Derek is very low which allows for optimum use of fertilisers. This means salt-sensitive plants will not be adversely affected by the growing medium.

Colour. Derek is a light brown/grey mottled colour which matures to a more even dark grey/black after successive irrigations. Most other non-peat products tend to be "peat brown" in colour. This can cause confusion to the general public.

Although Derek is distinctive in colour, it can be overlooked. The first overwintering (3-litre pot) observation trial on one nursery was concluded abruptly when nursery staff selecting for an order shipped off a good number of Derek-grown plants to a customer. They did not notice the difference and neither did the customer!

Efficacy. All trial work was carried out under commercial conditions. A no change policy was used—that is: no changes to the fertiliser regime, the irrigation, the standing down area, the potting machines, the pot size, planting material, or crop husbandry. The only change was the switch from nursery compost mix to Derek.

A trial was set up to compare peat, coir, and Derek performance in 2-litre pots from a spring potting. The nursery experience showed that coir required an extra kilo of OsmocotePlus 12 - 14 month spring formulation per cubic metre compared with the peat compost (Bulrush medium). Derek received the same OsmocotePlus rate as the peat compost—4 kg/m^3. Both the coir and peat compost mix also included 1.5 kg/m^3 dolomitic lime.

One hundred 9-cm peat liner plants of ×*Cupressocyparis leylandii*, *Mahonia japonica*, *Buxus sempervirens* 'Aureo-variegata', *Spiraea japonica* 'Snowmond' and *Ilex aquifolium* 'Alaska' were potted into each substrate.

Plants were potted by machine on April 1, 1992, and stood down on Mypex with overhead irrigation. The *M. japonica* was placed on Mypex in a shade house. All plants received the standard peat treatment. The standard herbicide programme of Ronstar 2G was applied after two weeks from potting followed by Flexidor in May/June. A final Ronstar 2G treatment was applied in September.

Height and width growth rates were analyses from April to late June (see Table 2 and 3). Derek gave significantly taller plants than coir in *Spiraea*, *Ilex,* and *Buxus*. In the width growth rates, Derek was significantly better than peat for *Mahonia*. *Ilex* in Derek was significantly better than in coir.

Table 2. Mean height growth rates (mm) from April to June in three pot substrates.

Species	Peat	Derek	Coir	LSD%
Spiraea	287 +	310 +	240 -	50.3
Ilex	108	125 +	75 -	36.2
Buxus	49	66 +	43 -	17.5
Mahonia	92	94	113	N.S.
×*Cupressocyparis*	192	206	199	N.S.

Values marked (+) are significantly better than values marked (-).

Table 3. Mean width growth rates (mm) from April to June in three pot substrates

Species	Peat	Derek	Coir	LSD5%
Spiraea	230	262	176	N.S.
Ilex	35	68 +	17 -	33.9
Buxus	44	61	57	N.S.
Mahonia	124 -	211 +	229 +	77.3
×*Cupressocyparis*	not recorded			

Values marked (+) are significantly better than values marked (-).

Across all species, neither coir or peat had a significant advantage over Derek in height or width. In general terms, Derek outperformed coir substrate with extra fertiliser and was as good as peat grown plants.

Trials of spring- or summer-potted rooted cuttings into liners, stood down on Efford sand beds or on normal sand beds with overhead irrigation, and 3-litre-pot trials have shown that Derek can produce plants of equal quality to peat without changing any aspects of husbandry. It should be remembered that today's peat production systems have been developed over the last 25 years. In just one year Derek has matched its performance. With fine tuning, superior plants to peat-raised plants may be produced in the future.

Breeding and Selection of Hardy Woody Plants in Bavaria

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INTRODUCTION

Weihenstephan, in Freising near Munich, is probably the biggest centre of agricultural education and research in Europe, and is known as the Green Centre of Weihenstephan. Plant breeding and selection work is being carried out on most agricultural and horticultural crops and the Institute of Pomology at the Technical University is the leader in the area of woody plants. This paper is a short description of the most important introductions in recent years.

IMPORTANT INTRODUCTIONS IN RECENT YEARS

Weiroot (Weihenstephan root) Sweet Cherry Rootstocks. Since the early 1960s there has been intensive research to develop dwarfing rootstocks for cherries. Eighteen selections of a less vigorous *Prunus cerasus* provenance from Landau in southern Germany were collected in the wild. Clone 11 showed the best compatibility with sweet cherries and was used for further breeding work. It had the disadvantage of having too many suckers. The clones 10 and 13 are still available but most promising seems to be the newer clone 158. There are plant breeders' rights on this clone which is being sold by the Nurseries Herr in Meckenheim and Hofmann in Langensendelbach. Experience to date with the Weiroot clones is that they have proved to be excellent in the Frankonian cherry growing area where they were trialed originally. However, there are occasional reports that they are not always as successful in other areas. Unfortunately, there have been too few proper trials done on these rootstocks and not a wide enough range of grafting combinations in other areas to date. Clone 72 is the most dwarfing and can be compared to M 2 in apple. Grafted plants need a stake. In general the weaker growing the rootstock the more difficulties it presents in the nursery, and afterwards in the orchard.

Plum Rootstocks Number 6 and 226 from *Prunus tomentosa*. These two selections from *P. tomentosa* have proved to be most promising as dwarfing rootstocks for plums. There are practically no incompatibility problems (the exception is 'Ontario'). Plant breeders' rights have been applied for. Plants are already on the market and can be obtained from the above mentioned nurseries.

'Weiki' (Weihenstephan Kiwi) from *Actinidia arguta*. This must surely have been one of the most successful introductions in Germany. After years of selection work the most cold-hardy clones were selected, three in all. They have survived the difficult climate of Upper Bavaria where temperatures can go down to -30°C. Interestingly, they start into growth early in the season but even if all the new shoots and flowers have been killed, new buds develop from nodes that have not yet shown signs of growth. These buds also have flowers so that a crop of kiwis is

assured. Over the past 12 years there has never been a year where there were not some fruit in Weihenstephan. Individual plants bear about 10 kg of fruit although in one exceptional case 30 kg were collected. Most plants sold are micropropagated. They are, however, very easy to root by conventional means. Cuttings can be taken practically the whole year round from rooted cuttings growing in glasshouses with supplementary light. In the first year after planting they must be protected from frost if they do not have a sufficiently hardened base. It is not true that Weiki is capable of self-pollination; male plants must also be purchased. The fruits are very tasty and are about the size of a gooseberry. They do not have to be peeled because they are hairless. There are no breeders' rights on 'Weiki'; only the name 'Weiki' is protected in Germany. Plants are sold through Hofmann, Langensendelbach.

In the Institute of Pomology, successful crosses between *A. arguta* (hardiness and hairlessness) and *A. deliciosa* [syn. *A. chinensis*] (size) have been carried out. They will be field tested in the coming years. So far no flowers have appeared.

Raspberries Resistant to *Phytophthora*. Growing raspberries has been called into question because of the rapid spread of a root disease in nearly all cultivars derived from the European form of *Rubus idaeus*. The American (var. *strigosus*) form is resistant. Therefore, the American cultivar Latham was used in a breeding programme in Weihenstephan. Plant breeders' rights have been applied for on a very promising selection which has excellent flavour, is easy to pick, and is high yielding. It does not appear to be susceptible to other diseases. The Technical University wishes to keep the plant breeders' rights for Germany.

Selection Programme for the Service Tree (*Sorbus domestica*). The service tree is enjoying a renaissance for two reason. Firstly, it is an endangered species in Central Europe. In the whole of Germany only about 3,500 to 4,500 older trees survive. Foresters have therefore decided to plant the service tree in increasing numbers, although there is no real market for the timber because so little is available for sale. Secondly, there is an interest in fruit production. The fruit juice acts as a natural preservative and it improves the taste of apple wine. The so-called Speierling (service tree) apple wine in Frankfurt may only have about 1% juice extract because it is so rare. Prof. Kausch von Schmeling—Germany's leading expert on this species—identified 60 trees which he thought to be promising for fruit production. These trees are growing throughout Central Europe and produce regular crops of larger than normal fruit. After examining the biochemical properties of all clones, 30 clones were chosen for propagating in the Fachhochschule Weihenstephan using *S. domestica* as the rootstock. A major problem has been the rejuvenation of the propagation material. Cutting back severely and growing under high temperature regimes in a glasshouse, as well as regrafting onto seedlings, seems to be working reasonably well. It will take many years to identify a number of promising new cultivars. These should be the first clones available for commercial exploitation.

Successes and Failures of Marketing—The Blooms Experience

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INTRODUCTION

Marketing, as defined by the UK Institute of Marketing, is "the management function which organises and directs all those business activities involved in assessing and converting consumer purchasing power into effective demand for a specific product or service to the final consumer or user so as to achieve the profit, target, or other objectives set by the company."

Until recently, selling, not marketing, is what most of the nursery stock industry has done to maintain its income. However, times are rapidly changing and this paper gives some ideas about marketing based on the experience that Blooms of Bressingham has had in marketing new plants and groups of plants, then turns to the present and future.

BLOOMS EXPERIENCE

In the 1960s, although Blooms was known for the breeding and introduction of hardy perennials, very little attempt was made to promote or market new varieties. The garden centre market was only just developing but my father, Alan Bloom, had begun promoting and marketing hardy perennials and their use in "island beds."

When I returned to the family business in 1962, I began to develop the collection of dwarf conifers and heathers—and over the years promoting this group of plants to what seemed an eager public.

Although we promoted new plants, it was a little ironic that the major promotion we were to do was a shrub not even raised by us. This was the first colour break in shrubby potentillas called, it would seem appropriately, 'Red Ace'. It was the first shrub to have the protection of Plant Breeders Rights and our successful negotiation to obtain world rights was to put us in the firing line, so to speak, in promoting new plants. This was in 1975 and after an enormously successful launch at Chelsea and pre-booked sales of over 200,000 plants it went on the UK market in September—only to turn yellow in the hottest summer Britain had experienced in 50 years.

We all know the problems of controlling plants and their environment and our next major promotion on *Phormiums*, the New Zealand flax, in 1979 coincided with one of the coldest winters for some years, leading to major losses of plants. But the path was set for Blooms to seek new plants and promote them through mail order and garden centres.

We had been instrumental in setting up a marketing cooperative of five independent nurseries, the Anglia Group, in 1969. However, in 1979 we left so that we could promote our own company brand name, Blooms of Bressingham, direct to the public.

Using newly designed promotional material we continued to promote new plants such as *Potentilla fruticosa* Princess™, *Spiraea japonica* Golden Princess™, *Choisya*

ternata Sundance™, *Juniperus* × *media* Gold Sovereign™, *Hebe* Margret®, and *Fragaria* × *ananassa* 'Frel' Pink Panda™, as well as many hardy perennials.

WHAT TO PROMOTE, HOW TO PROMOTE IT

Things have moved on, and we are now only one of many in the UK whose marketing is becoming increasingly professional with larger and larger sums being committed to it. But is it profitable to promote and market new plants? I believe it is, or at least it can be, but these days the markets are changing so rapidly that one needs to be aware of not only the potential but the pitfalls. Here is a brief guide as to what to look out for in deciding how to introduce, promote, and market a new plant.

The Plant. Avoid the instinctive reaction to select it because it is "a nice little plant." You will need to think of it as a product and assess it for the market it seems most suited for, i.e. garden centres, mail order, amenity, etc. Perhaps it is adaptable for several markets.

Culture. You need to think about what is the best way to propagate and grow your chosen plant — seed, cutting, micropropagation, grafting? Is it generally free from pests and disease—if not, what are they and how can they be controlled. You need to develop a production blueprint as soon as possible, and add to it as your experience grows. Whilst growing trials are necessary, increasing competition may mean pushing new plants forward without the benefit of a long trial period.

Plant Protection. If you have a new plant of potential importance, do not part with it to anyone without asking for a test certificate to be signed by the recipient—otherwise difficulties of ownership may arise, creating possible problems in obtaining plant breeders rights (PBR). PBR and plant patents are an insurance against the costs of promotion and marketing of a highly desirable and commercial new plant. They give longer term benefits to the company and, of course, royalty returns to the breeder. PBR should be applied for before the launch of a new plant—not only in the country of first introduction but ideally in the other major markets too. This takes some organisation and initial cost.

Marketing and Distribution. This stage is almost the most vital, assuming you have a marketable plant. A breeder or small nurseryman is unlikely to have the resources or knowledge to make full use of the potential of a new plant. The market is not just the UK any more but, potentially, the whole world. For that you need an organisation that can cover the UK and foreign markets either by themselves or, as is most likely, in association with other companies. Plants will need testing and assessing in different climatic and market conditions. Sales and distribution will need to be controlled and royalties collected.

Planning further and further ahead is becoming more necessary so agents have the opportunity to trial under a test certificate before introduction into any country. It has taken us a long time to get to that point at Blooms but at last we are beginning to get a more efficient distribution system with agents in most major world markets.

Launching New Products. So finally, after maybe several years of costly preparation, plans are prepared for a product launch. Remember, marketing is about creating a demand and to create a demand you must create publicity for the

plant. This should involve a launch date and as much media coverage as possible. The gardening press in Britain and in many other countries is generally hungry for good copy about new plants. The Chelsea Flower Show and other exhibitions are excellent platforms for a launch, particularly if accompanied by a celebrity. The markets need to be provided with all the pre-publicity material and distribution dates, and of course plants need to be at their best in appearance and quality when finally released to the public to buy.

The Financial Returns. Costs can be enormous—£30,000, £50,000, £100,000—even before a plant is sold. There are big risks to the marketing company and potentially big rewards if it goes well. In fact the marketing company, unless they are one and the same, has a potentially bigger risk than the breeder though both will usually get paid, or not, on results. Breeders need to be patient, knowing that it often takes time to test the plants and build the markets. With PBR and plant patents lasting longer than 20 years rewards should come if the foundation, the structure for production and marketing, is firmly built.

CONCLUSION

At Blooms we have had successes and failures. The failures almost always have come from not doing our homework sufficiently on the requirements of the plant under market conditions, being rushed into marketing too soon, or a combination of both. So we have now become much more methodical in our appraisal system for new plants, with the result that plants such as *Fragaria* × *ananassa* 'Frel' Pink Panda™ and *Hebe* Margret™ are working very well, despite occasional pirating attempts.

But new plants at Blooms are not only those with major across-the-markets potential. We select many plants which are just good garden plants but may not always look or grow well in containers. We do not always want to be orientated towards just a few major introductions. Our policy is to offer a wide range of new and unusual plants—perhaps some rediscovered—and to promote not only plants but ideas on how the gardener can use them. To broaden the market in such a way may be an even greater challenge for the present and the future.

The Commercial Exploitation of New Plants

David Clark
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IDEAL QUALITIES FOR NEW PLANTS WITH MAXIMUM COMMERCIAL POTENTIAL

Use this checklist to help decide whether a new plant deserves introduction: distinct from existing cultivars, attractive foliage, attractive fruits, evergreen, hardy, disease resistant, easy to grow in the garden, tolerates a wide range of soils, propagates easily, can be propagated all year round, easy to grow in nursery, flowers early in production cycle, looks well in spring, suitable for small and medium gardens, flowering over a long period, and retail price below £10. If you have a plant that meets all these criteria, you have a perfect plant and a sure winner.

OUTSTANDING PLANTS DESERVE OUTSTANDING NAMES

It can be argued that a good plant will sell despite its name. But why reduce the potential and slow up the popularity of a plant by giving it a non-selling name? I have great respect for the late Jack Matthews, of Matthews Fruit Trees who, in addition to being an excellent nurserymen, was a brilliant innovator. Back in the 1960s he started to promote hedging plants by giving them fancy names, such as 'Crimson Dwarf' for *Prunus* × *cistena*. This was a good example of making a plant "consumer friendly."

The potential of many new plants has been rather restricted by an inappropriate name and when giving a name to a new plant I suggest the following should be considered: easily remembered, descriptive of the cultivar, warm sounding, not offensive, not restrictive, internationally acceptable, and linked names for plant ranges.

The biggest selling rose cultivars have usually had very good names—Peace™, Super Star™, Fragrant Cloud™, and Silver Jubilee™. The same can be said for shrubs—*Potentilla fruticosa* Red Ace™, *Choisya ternata* Sundance™, *Scabioas* Butterfly Blue™.

PLANT BREEDERS RIGHTS

Plant Breeders Rights are the only fair and realistic way of rewarding breeders and plant hunters. It is surely also reasonable to protect chance sports and variations of existing cultivars. I am not aware of any nursery company which has a long term breeding programme for shrubs and before such a breeding programme can be put into place there needs to be some guarantee that a long term income is available.

The larger rose breeding companies, such as Kordes, Meilland, and Poulsen, are dependent on plant breeders rights and the royalties they generate, although it should be noted that the majority of their income is derived from the cut flower or pot plant cultivars, not garden cultivars.

It is costly to apply for Plant Breeders Rights and only a proportion of cultivars are worthy of protection. Cultivars which take a long time to build up stocks and

have a small market potential are obviously the most uneconomic. Current rates for obtaining plant breeders rights in the UK are:

	Application Fee (£)	Annual Fee (£)
Shrubs:	130	165
Roses:	50	50

The advantageous rates for roses have been negotiated by the British Association Representing Breeders, in its former guise of the British Association of Rose Breeders. In other countries the cost of plant breeders rights is very variable. I have just been quoted £1,500 to protect a cultivar in Italy.

Trade Marks Versus Plant Breeders Rights. Growers should understand the difference between Plant Breeders Rights and trademarks.

Plant Breeders Rights grants the holder the exclusive right to benefit from the new breed registered and prevents others from infringing the right by developing the same cultivar (variety) or producing that cultivar without the holder's consent. It does not, however, grant exclusivity of the right of sale or production. The owner of the right is under an obligation to grant licences of the right to others for their use, for which the owner will require a financial gain from a licence fee or royalty.

Trademarks are quite different in that exclusive rights vests in the use of the name or goods for which a trademark is registered. It does not prevent the goods themselves from being produced by another party, but prevents those goods being sold under the same name. It therefore follows that a plant breeder who relies solely on trademark registration will not be able to prevent others from exploiting his new cultivar—only exploitation of that cultivar under his trade name.

ALTERNATIVE WAYS OF EXPLOITING NEW PLANTS

There is no simple formula for exploiting all plants as it is inevitable that different plants will have different potential. The decision is also influenced by the capacity and structure of the company responsible for maximising sales. There are three factors that need to be taken into account: production capacity, sales organisation, and distribution systems. Very few companies, if any, have the existing facilities and distribution systems to maximise the sales of an outstanding plant. There are, of course, a number of alternatives with advantages and disadvantages. They include:

1) Launch and distribute the cultivar in conjunction with three or four other partners. However, bear in mind that the more partners there are the more complicated and difficult the exercise.

2) Make use of a royalty collecting agency such as the British Association Representing Breeders (BARB). It is a nonprofit organisation set up 19 years ago by three rose breeders. The BARB scheme has enabled rose growers to produce a wide range of new cultivars from breeders around the world and has been acknowledged as the most successful of its kind in the world. It has now been extended to include other ornamental plants, shrubs, and perennials. This will give even the smallest grower the opportunity in the future of growing a wide range of new plants with a minimum of hassle. At the same time it will enable small and

large growers who own rights to new cultivars to make these available to a much wider audience. The administration, collection of dues and policing will be taken over by the central agency.

How BARB Works. Each year a comprehensive list of cultivars "on offer" is distributed to registered growers. They are able to choose which cultivars, and the number of each cultivar, they wish to propagate. Regular reports on propagation are sent to central office which then invoices all the royalties due at agreed periods throughout the year.

The BARB system is regulated by two field officers who routinely visit all the licencees to discuss new cultivars, answer queries, and check that the grower is making the return on the correct basis. This ensures a proper return to the breeder and prevents unfair competition between licensed producers.

Royalty levels are set by the individual breeders, who pay BARB a levy on each plant grown by the licencees, and are administered by the Association.

BARB issues and administers licences, collects the royalty, and does all the relevant paper work, credit control, and field work. The royalties collected are disbursed back to the breeder monthly; bad debts are dealt with by BARB, as is all legal work. BARB also monitors changes in legislation.

The system has a number of advantages for the breeder or agent. For example, BARB is able to present the breeder's cultivars to a wider audience, and it plugs the breeder into a recognised, accepted, and proven system of royalty collection and control. It also provides breeders with vital financial and product reports on the performance of their cultivars.

Growers who become licencees are able to grow a wide range of new cultivars of both shrubs, perennials, and roses. They can make returns to one agency rather than to a lot of breeders all operating different schemes, and then receive one invoice document. They can keep up to date with all the information on new cultivars. BARB members can capitalise on national promotions for new plants.

PROMOTION

Point-of-Sale Promotional Material. Ideally, point-of-sale material should consist of coloured bedhead cards, coloured posters and individual coloured labels. Thankfully there is a British standard size of 8 in. by 6 in. for bedhead cards. This is the most important item of any point-of-sale material. Posters are effective but expensive. They must be bold and clear and can either be on paper, plastic or Correx, which has recently found favour as it is easily erected in the garden centre. However, I wish the industry could agree on a standard size for posters as this would enable garden centres to have permanent, or at least standard poster boards in and around the plant sales area.

The need for individual coloured labels varies with the type of plant. A variegated evergreen hardly needs a coloured label, while a deciduous short-season flowering plant definitely does. My own policy has been that if we produce a label it should be bold and create a very natural effect. I think most I.P.P.S. GB&I Region members will know the "True to Life" clematis labels.

Trade Promotions. "Rose of the Year" (ROTY) is another successful promotion by the rose trade but it could achieve even greater potential. To enter ROTY, rose growers submit promising new cultivars to a number of testing stations located

throughout the country, three years in advance of the ultimate year of introduction. Both professional and amateur growers judge the performance of the cultivars and select one winner at the end of 12 months.

Propagating material is then distributed to any rose grower who is BARB registered so that they are able to offer plants in the appropriate launch year. The ROTY committee organises point-of-sale material and a public launch at the Chelsea Flower Show.

Around 50,000 plants of the ROTY are sold in the first year and successful hybrids such as Sweet Dream™ now sell 140,000 annually. I believe the potential is probably at least double the current achievements.

NO STOCK NO SALES

Finally, the propagators role must be to ensure that enough stock of a new plant is available. There is nothing more frustrating for plant salesmen and garden centre operators than having demand for which there are no plants. The key, of course, is to pitch production at about 99% of the potential demand—it is of course much worse to have too many.

Launching New Plants—A Liner Producer's Job?

André Briant
André Briant Jeunes Plants, St Barthélémy d'Anjou, Cedex, France

WHY IS A LINER PRODUCER INTERESTED IN LAUNCHING NEW PLANTS?

It is part of a propagator's job to consider the launch of new plants. The liner producer is at the beginning of the nursery line and should offer the best range of varieties to really fit the needs of the plant market. And there is a demand for new plants.

A liner producer has many customers all over his own country and he also exports very often and sells large quantities, he is normally a good contact for the breeder of new plants.

Searching, selecting, and launching new plants is really a liner producer's job but it is not an easy one for him. He has no finished plants to show; he does not sell to a garden centre or to a landscape company but to a grower. So he is quite far from the final customer. When you want to sell a new plant you have to convince your customer, the customer of his customer, and the final consumer.

You can only do it if:

1) You are very selective on the new plants you want to launch.
2) You are very efficient at promoting to your direct customer.
3) You assist your customers with their promotions and cooperate with growers and distributors.

KEY FACTORS IN A SUCCESSFUL LAUNCH

Long Trial Period. A. serious experimental stage is important:

1) To precisely observe the plant and compare it with similar cultivars to be sure that it brings something new to the market.
2) To know exactly which kind of market the plant is really suitable for and what all the different possibilities are of using it.
3) We need to know: how to propagate it; how to grow it; how to sell it successfully; how hardy it is; whether it can stand full sun or shade; whether it can tolerate wet or dry soil; whether it will tolerate coastal conditions; how vigorously it grows; the size of the adult plant; whether it can be grown easily in containers; disease susceptibility; and so on.

It is also very useful to test the ornamental attraction of the new plants with groups of consumers, landscapers, and garden centre buyers.

Production in Quantity. Frequently we are too cautious and do not put enough plants into production. To really succeed in launching new plants we need big numbers; it is the only way to have an effect on the market.

It is evidently a risk which we are not always ready to take. But a good promotion campaign costs money and you can't pay for it with small quantities. Sharing the risk is also a good solution. Launching a new plant with four or five nurseries is a good way to produce large numbers and minimise the risk.

Quality and Intensity of Promotion. The customers of my own nursery are nursery growers so we have put most of our promotional efforts into the catalogue.

It is a 90-page catalogue and is illustrated with 170 colour photographs. We have both French and English versions. It is an investment of £50,000—conception, realisation, and despatch included. It is sent, of course, to our customers and prospective customers but also to the customers of our customers, such as garden centres, landscape businesses, landscape architects and local authorities.

Two basic elements of promotion are very important when starting: the name of the plant and the quality of the photographs.

Plant Name. The name must be suggestive, attractive and easy to remember. it is an element we never pay enough attention to. Sometimes there are English or French names which sound good in every country but generally it is preferable to give a name according to the country targeted for the plant promotion.

Unfortunately, too many nurserymen fall into the bad habit of renaming a plant to get round the laws on Plant Breeder's Rights or trademarks. For example they will name the *Potentilla fruticosa* Red Ace™ as "Red Joker" or *Choisya ternata* Sundance™ as "Moonslipper". It is, of course illegal if the plant is protected by breeder's rights, but it is legal if the plant is only trademarked. It may be legal but it is certainly not fair or honest, and brings confusion to the names and damages the promotion work done previously. I do think the entire trade should condemn such ways of working.

Photographs. The quality of photographs used in promotion is, in my opinion, a second basic condition for successful promotion. We need them for the catalogue to start successful promotions. You need them for your catalogue if that is your main selling tool; you need them on your exhibition stand; you need them for posters and colour labels for garden centres; and you need them for publicity in magazines. You always need them.

PLANT BREEDERS RIGHTS

Some are very much in favour, some are completely against Plant Breeder's Rights. Many have no opinion on the matter.

It is true that protecting plants is very expensive and to be really efficient the protection must be applied in all the countries where you want to sell the plants which makes it still more expensive. And the control of infringements costs a lot of money.

But it is still the best way to pay the breeder and to perpetuate research on new plants. In the long term it means more money for the breeder. When you have spent a lot of money for Breeder's Rights in five or six countries, on top of promotion expenses, you are obliged to develop the varieties to the maximum, and sub-licence them as much as possible. Again, you need large quantities to really benefit from all that you have done.

A good new plant which has been previously tested and which, because of its interest can be produced on a large scale, should be protected by breeders rights.

Sub-licencing is the best way to increase to the maximum the propagation of a new plant. Yes, to be the only one to launch a new plant is a great competitive advantage and it is very good publicity for your company. But to really make money in the long term with a new plant the best way is:

- To protect it with breeder's rights on an international scale;
- To sub-licence as much as possible;
- To manage a very good promotional campaign;
- To efficiently control all the infringements.

Ways Municipalities Use New Plants: How We Work in Nantes

Marc Mansuis
Nursery Manager, Nantes Municipal Horticultural Services, Nantes, France

The city of Nantes owes its horticultural status to its maritime history. The new plants brought back by the navigators and ship owners of the city were planted in the Apothecary Garden, before it became part of the Royal Botanic Garden, which itself comes under the Paris Museum. Those seafarers were responsible for introducing numerous plants into Europe, such as *Magnolia grandiflora*, the Virginia tulip tree, *Liquidamber*, *Sassafras,* and so on. Several Mayors of Nantes were also botanists, including Ferdinand Favre, who developed camellia culture at the turn of the century.

Nantes also has a mild, coastal, Gulf Stream climate, and soil with a low limestone content, which suited many of the new plants being brought back from overseas.

Thus the current Department of Green Spaces and the Environment is continuing a tradition of enthusiasm for new plants. At Nantes these are cultivated for two reasons: as botanical collections in their own right and for utilitarian uses. The collections are now being entered in the Conservatory of Generalised Plant Collections, which is being looked after by the Association of Botanical Parks and Gardens in France. The collections include *Magnolia*, *Quercus*, *Lonicera*, *Ilex*, *Iris*, *Viburnum*, *Camellia,* and *Rosa*. The plantings serve mainly as a conservatory for collections of rare plants and are, therefore, of educational value to the public. Each park has one or more complete collections, and conducted tours of the collections are available to the public.

New plants are either bought or exchanged with other botanic gardens. Some are raised from seedlings on our own nurseries, such as *Chamaecyparis lawsoniana* 'Bleu Nantais'. We are currently working on a new sequoia with a very dense habit.

Our collections also act as a source of breeding or propagation material to provide plants with characteristics required for modern usage, such as ground cover plants to reduce the need for chemical weed control; narrow-crowned trees for planting in narrow streets; the selection of self-cleaning plants within the buddleia, camellia, rose, and potentilla families.

The most revolutionary plant we have dealt with has been the ground cover rose. It appeared at a time when costs of managing public open space were increasing dramatically, but it enabled Nantes to increase its green space from 500 to 600 ha without increasing personnel.

We are interested not only in the proper management of public spaces to enhance our city's reputation but also in the promotion of horticulture and the love of plants. We must be a show-case for professionals.

New Plants for Amateur Gardeners— a Retailers View

Mr. Wuhrlin
Head of Marketing, Jardiland

Jardiland (French garden centre group) is a chain of 70 franchised garden centres which had a turnover of 1.1 billion French Francs—one third of the French garden centre market. The aim of this paper is to discuss the marketing of Jardiland, and how Jardiland markets new plants.

For a long while, marketing attention focused only on the product. We were in an equipment-based market which tended to react to demand, rather than make offers to stimulate it. Today, customers are increasingly selective. Our thoughts are increasingly about the customer, rather than the product, and we are increasingly doing what we call "marketing of the demand." We no longer content ourselves simply with meeting existing demand, we want to use marketing to actively develop it.

To do this we must get to know the customers, and to realise that they, too, change. Today our customers are more and more aware of ecology, but they know less and less about the techniques of gardening. They do, however, want an activity that requires some acquisition of knowledge, which will give them a sense of purpose and allow them to be creative.

Customers expectations have developed enormously. In the absence of inflation, price comparison is easier and the customer more watchful. In the absence of growth and in a discouraging financial climate, top-of-the-range products are often bought in response to the customers need for compensation.

Our position as a plant specialist leads us to direct our efforts towards the promotion of top-of-the-range products, including, especially, new plants.

For new plants, as for all products, a failure in launching is a result of a failure in one of the following four factors: quality; price; communication (publicity); distribution.

Quality. The conference has already covered aspects of quality of new introductions, as a retailer I would simply say, do ensure the qualities of a new product do not compete with existing qualities, for example do not introduce beauty at the expense of hardiness.

Price. Price is one factor that kills the majority of products at the outset. The added value of a new plant must be justified, and you have to remember the poor botanical or horticultural knowledge of customers is a handicap. Plant breeders, growers and some wholesalers have pricing policies that are dangerous for the products they are trying to promote because they have purely and simply forgotten the customer.

It is impossible to justify to the customer the difference of four-to-one on the prices of two apparently identical roses. The example of the rose can be generalised to cover the other nursery species which may, for the customer, be equally good as substitutes and bring the same degree of satisfaction. Every intermediary in the supply chain must think in terms of the profit margin against value rather than the profit margin alone. It is often more profitable for the retailer to sell a number of items with a reasonable margin than a few with a large one.

The Distribution Chain. It is useless creating new varieties if they are not made available through the distribution chain. This important condition is barely fulfilled today because the promotion of new plants does not only require them to be shown but demonstrated. The distributors are not always able to ensure demonstration and do not always perceive interest in it.

Publicity and Communication. Publicity to the final consumer is often lacking, the main target is usually the growers. The nursery trade and retailers need to work in partnership to promote new products most effectively. The nursery trade's new products should be a priority for retailers too.

Plant introducers must organise the launching of their products directly with retailers because it is the retailer who has the closest knowledge of the final consumer.

New Plant Introductions—The European Scene

Harry J. van de Laar
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My contribution is a slide presentation of new and novel woody and perennial plants. Some of these novelties are grown in large quantities, especially in nursery areas. Others are new and only obtainable in very limited quantities, often directly from the raiser. Most of the novelties which I will show are extremely hardy under Dutch climactical conditions. On the other hand a number of plants have been shown which Dutch growers have in their nurseries, often in large quantities, for export to countries with a milder climate. A good number of the plants have received awards such as an Award of Recommendation, an Award of Merit, a First Class Certificate, and/or awarded a Gold or Silver Medal at several exhibitions, for example "Flora Nova" at Boskoop. These awards have been given by the Judging Committee of the Royal Boskoop Horticultural Society. The Judging Committee will celebrate its centenary in 1994.

Since 1964 all the awarded plants have been published with more or less extensive descriptions in Dendroflora, a yearly publication of the Royal Boskoop Horticultural Society and the Dutch Dendrology Society. For a number of years, most of the plants receiving awards have a full colour photograph in this journal paid for by the raisers or the Dutch introducers.

NOVELTIES CULTIVATED IN HOLLAND

Acer campestre 'Royal Ruby'—young leaves purplish-red, deepening with age.

Amelanchier ovalis 'Helvetia'—very dwarf habit, flowers creamy white, fruits bluish-black, numerous.

Aucuba japonica 'Fukurin'—leaves bright green, bordered golden-yellow.

Berberis × *lologensis* 'Mystery Fire'—bright orange flowers, can be propagated from cuttings, instead of grafting on *B. thunbergii*!

Berberis thunbergii 'Pink Attraction'—habit spreading to more or less upright, leaves purple, young growth rosy-white variegated.

Buddleja davidii 'Masquerade'—leaves creamy-white variegated, flowers deep purplish-red.

Buddleja davidii 'Summer Beauty'—flowers bright purplish-red, July-August.

Cedrus deodara 'Blue Snake'—needles grey-blue, irregular ornamental habit.

Cedrus deodara 'Feelin Blue'—dwarf spreading habit, foliage blue-grey.

Chamaecyparis pisifera 'Tamu-himuro'—dwarf, globular form, foliage bluish-grey, good indoor plant.

Clematis 'Anita'—white flowers, deep green foliage (interesting hybrid).

Clematis 'Helios'—small, golden-yellow, flat-open flowers, very abundant.

Clematis montana 'Freda'—bright rosy-red flowers, purplish foliage.

Clematis montana 'Mayleen'—large, clear pink flowers, purplish foliage.

Cornus florida 'Cherokee Daybreak'—leaves variegated, flowers white.

Cornus florida 'Cherokee Sunset'—leaves strongly variegated, flowers red.

Cornus kousa 'Satomi'—flowers rosy-red (during hot weather pinkish), June.

×*Cupressocyparis leylandii* 'Gold Rider'—foliage bright golden-yellow, does not scorch in full sun.

Cupressus macrocarpa 'Wilma'—foliage yellow to light green in the shade, an improvement on 'Goldcrest, excellent indoor plant.

Cytisus × *beanii* 'Osiris'—more compact than the type, flower golden-yellow.

Cytisus × *kewensis* 'Niki'—branches weeping when grafted on standards of *Laburnum anagyroides.*

Cytisus multiflorus 'White Bouquet'—dwarf form, flowers creamy-yellow.

Cytisus × *praecox* 'Twilight'—flowers light yellow, purplish-red in bud, branch sport of *C.* × *praecox* 'Hollandia'.

Escallonia laevis Gold Brian® —large, golden to greenish-golden leaves, flowers deep pink.

Euonymus fortunei 'Harlequin'—spreading habit, leaves white spotted.

Euonymus fortunei 'Interbolwi' Blondy®—leaves splashed golden-yellow.

Forsythia × *intermedia* 'Courtalyn' Week-End®—upright growing habit, flowers golden-yellow, very abundant.

Hosta clausa var. *normalis*—leaves lanceolate, glossy green, flowers deep purple, stoloniferous.

Hydrangea macrophylla 'Blaumeise' ('Blue Tit')—ray florets deep blue.

Hydrangea macrophylla 'Masja'—bright red flower heads, rich flowering.

Hydrangea macrophylla 'Rotkehlchen' ('Redbreast')—ray florets deep red.

Hydrangea serrata 'Benigaku'—rosy-red ray florets, bluish fertile flowers.

Hypericum × *dummeri* 'Peter Dummer'—flower large, looks like a dwarfer growing 'Hidcote'.

Ilex aquifolium 'Canadian Gold'—leaves golden, bronzy-red when young.

Juniperus × *media* 'Gold Star'(true)—broad spreading habit, foliage golden.

Juniperus virginiana 'Blue Arrow'—looks like an improved 'Skyrocket', much more healthy.

Laburnum anagyroides—flowers golden-yellow, very abundant.

Larix kaempferi 'Little Blue Star'—extremely dwarf form (witches broom), grayish-blue needles, good as a dwarf standard.

Lonicera nitida 'Red Tips'—glossy green leaves, young growth purplish-red.

Lonicera nitida 'Silver Beauty'—small leaves, bordered silvery white.

Lonicera periclymenum 'Cream Cloud'—white flowers, vigorous grower.

Malus 'Adirondack'—large, white flowers, very dwarf habit.

Paeonia 'Maria Antoinette'—brilliant red, single flowers in May.

Penstemon digitalis 'Husker Red'—leaves purplish, flowers almost white.

Picea pungens 'Bialobok'—needles silvery-blue, soft yellow in spring.

Pieris 'Flaming Silver'—white variegated branch sport of 'Forest Flame'.

Pieris 'Mouwsvila' Havila®—creamy-white variegated branch sport.

Pinus jeffreyi 'Joppi'—dwarf selection, very slow growing, long needles.

Pinus 'Pierrick Brégeon'—dwarf, globular habit, needles fresh green.

Potentilla fruticosa 'Limelight'—large, creamy-yellow flowers.

Potentilla fruticosa 'Snowbird'—flowers pure white, semi-double.

Prunus incisa 'Mikinori'—light pink, semi-double flowers, blooms at a very young stage.

Prunus laurocerasus 'Goldglanz' ('Golden Lustre')—leaves yellowish, broad upright growing habit.

Prunus laurocerasus 'Renlo' Renault Ace®—upright habit, leaves glossy green, excellent for hedges.

Rhododendron 'Rendez-Vous'—dwarf growing, flowers light red, fading to almost white, nice shaped foliage.

Rhododendron 'Simona'—soft creamy-pink with orange-brown blotch.

Sambucus nigra 'Madonna'—leaves fresh green, bordered golden-yellow.

Skimmia japonica 'Rubinetta'—like 'Rubella', floriferous at young stage.

Skimmia japonica ssp. *reevesiana* 'Ruby King'—male, very floriferous, buds almost as deep as in *S. japonica* 'Rubella', very useful for florists.

Styrax japonica 'Pink Chimes'—flowers nodding, soft pink, very abundant.

Syringa patula 'Miss Kim'—buds purplish, flowers light purple, strong scent, numerous, dwarf, bushy habit, very hardy selection.

Taxus baccata 'Green Diamond'—globular dwarf form, very slow growing.

Thuja occidentalis 'Barabits Gold'—pyramidal, fairly narrow habit, foliage deep golden-yellow.

Tiarella cordifolia 'Oakleaf'—flowers whitish, leaves purplish in autumn.

Viburnum rhytidophyllum 'Superb'—brownish-pink buds, large flower heads, red fruits in August-September.

Weigela 'Courtalor' Carnaval®—flowers white with pink flush, deepening with age, in great profusion.

Weigela florida 'Victoria'—flowers purplish-red, leaves deep purple.

Weigela 'Red Prince'—the most red weigela, extremely frost resistant.

Production and Marketing of Roses in the U.S.A.

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CALIFORNIA PRODUCTION SYSTEM

In California, roses are field-grown on a massive scale in the central San Joaquin Valley, an area renowned for fruit production, viticulture, and nuts. The valley floor is a vast, level area of fertile soil, with a system of pipes and canals bringing water from the surrounding mountains. It is virtually frost free, and summer temperatures are consistently high. Mexican immigrant labour is freely available. Jackson and Perkins, at Wasco, currently has an annual production of 14 million roses. Other large growers such as J and M Roses and Weeks also produce several million roses per year. Possibly 70% of America's roses are produced in California and shipped bareroot to wholesalers and processors in the populated areas of the South and the Northeast.

There is an "accepted" Californian way of producing roses, which is used with only slight modifications by all the major growers. It is very different from the European system, but has been developed for an area where roses start blooming in gardens in early April. For garden roses the standard rootstock is 'Doctor Huey', a *Rosa multiflora* selection. Each grower has a hedge or bed from which hardwood cuttings are taken and lined out with a stock planter in March. At the same time, stocks of *R.* 'Manettii' are lined out in a similar manner to be budded with cut-flower cultivars for selling as one-year plants for glasshouse forcing. A high percentage of the cuttings (80% is claimed) will have rooted in time for budding the following March.

Irrigation is usually by the furrow system, whereby water is pumped from a canal to giant manifolds at the top of the fields from where it is allowed to run down, under gravity, in the shallow furrows left between the rows. Earth-moving equipment, guided by laser, is used to produce the correct gradients in fields prior to planting. Jackson and Perkins also operates a traveling boom irrigator over half a mile long in one field.

Budding, with cold-stored budwood, starts in early April, and is usually undertaken by itinerant Mexican gangs on a contract basis. The operation is physically similar to that used in the U.K., apart from the difficulties inherent in using hard buds. Work rates are comparable, on an hourly basis, but federal labour laws limit the working day to 8 hours, making 2,500 buds per person an acceptable rate.

Plants for greenhouse forcing are grown in the "one year garden system". The *R.* 'Mannetti' stocks are "crippled" by bending over the top of the stock at 15 days after budding. This forces the bud to grow out, and the stock is headed back 45 days later. The grafted plant is lifted in November (six months after budding) and sold as a "started eye" to a glasshouse cut flower grower. Garden roses are grown on the "two year garden" system. "Crippling" is practiced by some growers, but in all cases the stock is headed back during the first growing season, and the bush pruned, by tractor mounted circular saws, during the following winter. A second full growing season ensures a strong, bushy plant. Lifting begins in November, delayed by the difficulties of inducing dormancy in the Californian climate, and the need for ripe

[1]Mary Helliar Travel Award 1991

budwood to go into cold store.

Standard or "tree" roses are usually budded on stems that have been run up from ordinary stocks, but J and M Roses, of Cutler, insert a 4-ft hardwood cutting of 'Doctor Huey', and bud it during the first season.

It is considered necessary to use soil sterilisation prior to planting, and this is usually done by contractors injecting methyl bromide under polythene sheeting at a cost of $1,000 per acre. Weed control is mostly mechanical and pest and disease control mainly uses bupirimate. California has very strict environmental protection laws, and an operator certification scheme, similar to that introduced under the U.K. Food and Environment Protection Act, is in force. The range of pesticides available for use is probably smaller than in the U.K.

This, then, is the standard Californian system for producing bush roses. It is also used in Arizona where it is even hotter and drier, and water has to be extracted from bore holes. There is fairly widespread agreement that to produce a first grade rose using this system costs around $1 (65p) per plant.

TEXAS FIELD PRODUCTION SYSTEM

The bush rose production system in Texas is modified as a result of the climatic differences. The main production area, around Tyler in East Texas, has relatively high rainfall, high summer temperatures (often accompanied by relative humidity approaching 100%), regular winter frosts down to 0°F, and tropical storms are common. This is an area of small truck farms set in undulating wooded country. No one is quite sure why roses became such a popular crop in this area, but it seems to have been promoted as an alternative source of income when cotton became uneconomic as a small scale crop in the 1920s and 1930s. The local industry is currently worth $10 million annually.

Rootstocks tend to be either 'Doctor Huey', 'Brooks 56', or the individual grower's own selection of *R. multiflora*. Frost can delay rooting so that many stocks have barely started root initials before budding.

Skilled labour is often hard to find for the smaller growers, with Mexican contract gangs employed only by organisations such as Co-Operative Growers. The climate encourages weed growth, so expensive hand hoeing and herbicide spraying are necessary; disease is also favoured by the climate, and weekly sprays are necessary to keep black spot at bay. No irrigation is provided and no "crippling" is practiced. Yields of 52% to 55% are the target but yields can be as low as 10% (of cuttings inserted). Unit production costs of around $1 are quoted. This can only be as a result of low labour costs, with little being accounted for family wages.

MINIATURE ROSE PRODUCTION SYSTEMS

Two systems of miniature rose production were studied by this author. At Jackson and Perkins, miniatures are grafted onto *R.* ×*odorata*. The scion and stock are bench grafted, tied with rafia, and struck in a rockwool cube under mist in an open sided, lath-roofed shade house.

Ralph Moore (California) and Mark Chamblee (Texas) both propagate miniatures using soft leaf-bud cuttings inserted in trays. Rooting is rapid (14 days), and thereafter Moore uses an intermediate pot-liner stage for single cuttings, while Chamblee pots three rooted cuttings directly into a final 4-in. pot. With both systems, propagation takes place throughout the summer period, as long as

material is available.

SHRUB ROSE PRODUCTION SYSTEMS

While propagation of miniature roses from cuttings is not unusual, in Texas, Mike Shoup's system of shrub rose production is probably unique. A wide range of "old garden" and modern shrub roses, representing all the major groups, are propagated from cuttings and grown on as container plants. Four-inch pencil-thick cuttings are inserted under mist in October/November. Rooting takes 2 to 3 weeks with most cultivars, although with some, it may be delayed until spring. More vigorous cultivars are potted straight into a 2-gal container, while most cultivars pass through an intermediate, pot-liner stage before being final potted in May. In both cases there is a bushy, saleable container plant available in 9 months from striking. For bareroot mail order sales the plants are simply knocked out of the pots, and surplus compost shaken off.

CONCLUSIONS

When one strips away the obvious differences of climate and scale, there are many similarities to the U.K. rose industry. While reliable figures are hard to establish, there is no doubt that production is declining from a peak in the 1960s. Jackson and Perkins' output of 14 million has fallen from a figure of 20 million only five years ago and this seems fairly typical.

The basic field production system is suitable only for regions with a Californian climate, and is not even really effective in Texas—the European system based on lining out seedling rootstocks would be an advantage there, if suitable clones were available. For early budded stocks in the south of England, there may be some benefits to be had from experiments with "crippling" to induce buds to grow out during the first season, but timing would be critical and consistent results essential; at the moment "shot eyes" are seen as a nuisance as much as anything else.

The most interesting area in production terms is that of propagation from cuttings. The field budding procedure is physically demanding and expensive in labour. Skilled budders are becoming harder to find, and young people today rarely have the patience and dedication to learn the job properly. Despite "budding-guns" and self-powered trolleys, the operation does not lend itself to mechanisation. These factors have tended to keep the rose business in the hands of specialist growers, who have a vested interest in maintaining the "mystique" of the field budding operation. The arguments have been advanced that own-root roses are less hardy, and less colourful, and that many cultivars can not be struck from cuttings.

The widespread use of micropropagation to introduce new cultivars of landscape roses has disproved the first two points, and the experience of Ralph Moore, Mike Shoup, and others has gone a long way to disproving the third. Techniques are available to produce a wide range of cultivars from cuttings, and in the future "rootability" may well be a factor to be assessed in introducing new cultivars. Budded roses may soon have the same status as grafted rhododendrons do today. Micropropagation may have a role to play in this "own-root revolution", but the American experience suggests that its routine use in production will be limited by cost.

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The Influence of Juvenility on Plant Propagation

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Vegetative propagation of woody tree species is often difficult, mainly because of poor rooting. For example, the effects of age, clone, and nutrient level on the rooting of *Picea abies* is shown in Table 1.

Table 1. Rootability in cuttings taken from *Picea abies* trees of different ages, clones, and nutrient levels.

Clone	Age	Nutrient level	Rooting (%)
F470	3	normal	82
1801	10	poor	23
1802	10	poor	11
1803	10	poor	0
1804	10	poor	14
1805	10	poor	6
1806	10	poor	13
1807	10	poor	1
1808	10	poor	1
1809	10	poor	8
1810	10	poor	14
1811	10	poor	30
1812	10	poor	7
1813	10	poor	30
1819	12	normal	24
1820	12	normal	20
1821	12	normal	27
1822	12	normal	51
1823	12	normal	45

The rooting percentage of cuttings from 12-year-old trees ranged from 20 to 51%, while cuttings from 3-year-old trees (clone F470) rooted with a mean of 82%. The effect of nutrient level (normal vrs. poor) is seen by comparing the 10-year-old material (poor nutrient level) with the 12-year-old material (normal nutrient level). Better rooting was achieved in the older material—which should give lower rooting, but the normal nutritive level altered the rooting response. Even with improved rootability of the *Picea* cuttings by treatments such as a better nutrient level of the mother-stock material, it is still difficult to obtain satisfactory rooting results with mature material.

One way to avoid the problem of rooting loss associated with aging is to propagate from juvenile material. However, because valuable genetic traits are only known in most cases at maturity, cutting propagation is of limited value.

In seedling populations, variation in genetic traits is continuous. Therefore, through selection and vegetative propagation large genetic gains can be achieved.

However, if these selected plants are propagated sexually, the seedlings will exhibit large genetic variation when compared to the vegetatively propagated mother material. Therefore, the only way to retain the superior genetic traits is by vegetative propagation after rejuvenation of the mother material.

To bring back the ability of aged tissue to root easily, there is a need to understand the aging process in plants. Information on the biochemical basis of the aging process is limited, but physiologically it is known that tissues increase in maturity with increasing distance from the roots.

In practice, there are several ways to return the tissue back to an easier rooting condition. From a practical point of view, rejuvenation or reinvigorization can be achieved by:

1) Hedging. This practice is the most widely used method. As with shoot proliferation from axillary buds in micropropagation, the treatment results in reinvigorization, but adventitious shoots also can be induced. With hedging the aging process is arrested at about the age defined by the distance from the root.

2) Adventitious shoot formation. Adventitious shoots are usually juvenile. Suckers are usually adventitious, but epicormic and stump sprouts can be either adventitious or axillary.

3) Epicormic shoots, stump sprouts and suckers. Such shoot types arising close to the roots and are the most juvenile.

4) Grafting. Repeated regrafting on juvenile seedling rootstocks has resulted in rejuvenation of some species.

5) Tissue culture propagation. This can lead to either adventitious shoots or shoot production from axillary buds. Tissue culture propagation will usually results in reinvigorization, but if adventitious shoots are induced, the tissue will be rejuvenated.

Practical work in our tissue culture laboratory on *Crataegus*, *Tilia*, *Prunus*, and *Quercus* have shown, by use of axillary micropropagation, a high degree of reinvigorization. At this stage in our work we haven't been able to conclude anything about rejuvenation.

Why We Are Using Micropropagated Plants.

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INTRODUCTION

Back in 1986 we wanted an alternative way to produce *Clematis*. With help from consultants from the Danish Nursery Association, we decided to use micropropagated plants. We had a commercial laboratory carry out the propagation and deliver the plantlets to our nursery where we would grow them into saleable plants. We built a growth room where the plants were transferred from the test tubes to soil. Our decision to use micropropagated plants was based on the following reasons:

- To have healthier plant material.
- To obtain plants better suited for production, i.e. with more lateral bud breaks.
- To have available a continuous production of difficult-to-root plants.
- To have a method where we easily could mass produce new cultivars, or plants free from known diseases such as viruses.

We new this would be a large task, and began a collaboration with a commercial laboratory in Arhus who would develop the protocol for micropropagation of *Clematis*. At the same time, we were working with plant material of easy-to-micropropagate plants, such as *Hydrangea* and strawberries, which we received from Dæhnfeldt. However, at the time we were ready to start the production of micropropagated *Clematis*, the commercial laboratory closed.

Therefore, we had to start over again with a new partner, Lars Sommer from Hedeselskabet. At present, we are at the point of starting commercial production. We are now receiving tubes with micropropagated plants twice a week. At last, we believe that we have everything under control. The first plants have already left the nursery, and many more are in production.

HOW FAR ARE WE TODAY?

To get to the point where we are today, we have looked into and established the following transplanting parameters:

- Relative humidity: 80-85% RH.
- Temperature: 22°C.
- Time in the growth room: 2 to 3 weeks.
- Soil mixture: Jiffy blocks 40 × 40, 60 in a tray.
- Irradiance and CO_2: Photoperiod of 18 h, but still have to look further into these parameters.

THE FUTURE

We would like to be able to propagate all *Clematis* cultivars in this way and have a continuous production system. This will ensure that all our plants are healthy,

genetically uniform, and a better product. Already, we can see that the micropropagated plants are much better than those produced by the old system. This have given us confidence that we made the right decision in 1986.

Possibilities and Disadvantages of Genetic Variation

Kirsten Brandt
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INTRODUCTION

Plants grow by division of cells in the meristems. Normally the new cells are exact copies of the original cell, so every shoot on a plant has the same (genetic) characteristics. This also holds if the shoot is used as a cutting or in micropropagation because the vegetatively propagated plants are genetically part of the same plant.

However, mistakes may occur during cell division and so cells with new genetic characteristics appear. This is called mutation and is the basis of occurrence of off-types with characteristics other than those of the original plant.

MUTATIONS

The advantage of mutations is that usually only one characteristic changes at a time. If it is good (e.g. compact growth, a new flower colour), the off-type can be used directly as a new cultivar without a need for further breeding. The disadvantage is that new characteristics are usually bad (e.g. slower growth), and thus only show up as loss of uniformity. Problems with genetic variation can be prevented by using only the best plants as stock plants and renewing the stock plants when a certain number of plantlets have been produced. This will happen sooner when using micropropagation; however, by using good tissue culture techniques the number of genetic off-types can be kept as low as for cuttings.

The risk of mutations is not constant, it is known that it can be raised by using irradiation or certain chemicals. The risk of off-types also differs greatly among species and cultivars. Chimeras, plants that have genetic differences between cell layers within the same plant, have a particularly high risk of off-types. Many cultivars with variegated leaves or marbled bracts are chimeras. Such plants are unstable when propagated—both as cuttings and in tissue culture.

MICROPROPAGATION

It is a problem in micropropagation that some kinds of off-types, such as changes in flower colour, are difficult to detect during propagation. Certain tissue culture techniques, such as callus culture and adventitious shoot formation, increase the risk of variation; however, this can be exploited as an advantage in mutation breeding. In addition, one must also be aware that the hormones used in

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micropropagation can induce other types of aberrant growth, such as fasciation (brooming) and vitrification (glassy leaves). Although these aberrations are not genetic variation, for growers such aberrations are often worse than mutations because a majority of the plants in a lot may be affected.

By using high concentrations of hormones higher growth rates can be achieved in tissue culture, giving cheaper plants but also a greater risk of both genetic and temporary aberrations. Because of this it is important that the laboratories use strict quality control procedures and consider the risk of unwanted variation when choosing varieties and propagation techniques. Growers can reduce the risk of unpleasant surprises by using only plants from laboratories with a good reputation and by reporting quality problems to the laboratory.

Only few documented examples exist of serious problems due to genetic variation after micropropagation, but the micropropagation is often blamed when no other explanation for bad results is known. If a bad plant "grows out of it" the problem has not been genetic.

Micropropagation and Plant Health

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INTRODUCTION

When plants are asexually propagated, there is always a risk of diseases being transferred. This is especially a problem when the disease is caused by a virus. In the past the only way to avoid this problem was to select stock plants that were not infected. Since the beginning of the 1950s, research has shown that it is possible to inactivate viruses in plants with heat.

TEMPERATURE EFFECTS

Increasing temperature increases the probability of infection. Not only do plants grown at high temperature have a higher risk of infection, but the subsequent multiplication of the virus is also temperature sensitive. Some viruses grow best at a high temperature, whereas others prefer a low temperature. High temperature can also often cause the symptoms of an infection to disappear, but as soon as the temperature decreases, the infection symptoms become visable again. This temperature effect is important because one may assume the infection occurred simultaneously with the appearance of the symptoms.

When it was shown that high temperature can inactivated viruses, a tool became available to treat infected plants. The temperature tolerance of plants is very unpredictable. Carnations will withstand 37°C for several month, whereas *Pelargonium* exhibits severe disorders such as etiolated shoots after only 3 weeks.

TEMPERATURE TREATMENT PROTOCOL

Plants that are in active growth are placed in incubators maintained at a constant temperature. The temperature selected may vary between 34 and 37°C, most often 34°C is used. It is important to keep the plants well watered, fertilized, and at a sufficient level of irradiance during the temperature incubation period. A 16-h photoperiod is used for most plants. The duration of the treatment will depend of several conditions. For most plants, 3 to 4 weeks is sufficient but as long as several month may be needed. It is unusual that a virus following treatment is absent from the whole plant, but it seems to be absent from the young growing shoots. If a plant is propagated from the apical meristem of a shoot, it will most likely be free of virus. Table 1 shows the effect of treating apple trees at 37°C for various lengths of time.

Stockplants were heat treated for various lengths of time. Shoot tips from heat treated plant material were used for further propagation. Out of 96 heat treated plants, infection was only observed in six shoot tips.

MICROPROPAGATION

In micropropagation only the shoot meristem is used. It is possible to use a growth medium where internal fungal and/or bacterial infections can be detected. It is thereby possible to discard such infected material at an early stage. If the stockplants have been infected with a virus, the plants can be heat treated before the meristems are used for propagation.

Table 1. Heat treatment of mosaic virus infected apples (*Malus domestic* 'Ingrid Marie').

Treatment	Infected plants (%)
Control, untreated stockplants	100
Heat treated stockplants (37°C, whole plant)	100
Shoot tips from stockplants at 37°C for 20 days	17
Shoot tips from stockplants at 37°C for 30 days	0
Shoot tips from stockplants at 37°C for 40 days	3

Stock Plant Material. It is important that the stock-plant material has been selected for genetic uniformity and that the health status in known. If the plants have a virus infection, one must know which virus is present. When plants are grown in a greenhouse, shoot tips from growing plants are used for micropropagation. If the stock plants are field grown, dormant buds are used.

Micropropagation as a Method for Propagating Virus-Free Plants. Micropropagation can be used, not only for making plants free of known diseases, but for the mass propagation of plants. It is possible to produce 1/2 to 1 million plantlets from a single cutting. However, some risks are involved and the method may only be used on genetically stable plants. Examples of genetically stable plants are fruit trees and strawberries. At the other end of the scale is *Pelargonium* which is very unstable. If *Pelargonium* shoot material is grown on a medium with a high cytokinin level, callus and adventitious shoots will develop. Such shoots may have mutated, and those mutated shoots could produce abnormal plants.

Testing Micropropagated Plants for the Presence of Virus. The newly propagated plants must first be declared free of the particular virus(es). The virus may be present at a low concentration after heat treatment, and testing is very important. In addition, the plants must be kept isolated from the surroundings and tested regularly. If the disease has not been found within 1/2 to 1 year, the plants may be declared free of those diseases they have been tested for. For field-grown plants, at least two growing seasons are needed before they may be declared free.

Table 2. Examples of important crop plants which have been made disease free by micropropagation.

Plant	Virus eliminated
Euphorbia pulcherrima	Poinsettia mosaic virus
	Poinsettia cryptic virus
Solanum tuberosum (potato)	Potato virus Y, A, X, S, and M
Kalanchoë blossfeldiana	Kalanchoe latent virus
Populus blasamifera	Populus mosaic virus
Ribes red current group	Raspberry ringspot virus
Malus pumila, M9	Chlorotic leafspot virus
	Epinasty virus

Artificial Seeds in Micropropagation

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DEFINITION OF SYNTHETIC SEEDS

In the broadest possible sense, artificial seeds are a way of transferring somatic embryos or shoots from sterile tissue culture to nonsterile conditions, with or without an artificial seed endosperm. In a strict sense it is a somatic embryo with an artificial endosperm or seed coat. Thus, artificial seeds have no direct relation to the propagation method.

Redenbaugh et al. (1991) define the following four types of artificial seed:

- Uncoated, desiccated synthetic seeds
- Coated, desiccated synthetic seeds
- Coated, hydrated synthetic seeds
- Uncoated, hydrated synthetic seeds

The major research effort has been conducted with coated, hydrated synthetic seeds.

Encapsulation has several advantages over traditional acclimatization and soil establishment of somatic embryos.

1) Micropropagated plants can be delivered directly to the nursery/greenhouse without acclimatization. Acclimatization and several handling steps are saved.

2) The artificial endosperm and seed coat protect the embryo during transport, storage, handling, and sowing.

3) The small size of the propagule has advantages in distribution, storage, and transport.

4) You can supply the artificial endosperm with substances such as nutrients for use during germination, hormones that regulate germination, beneficial microorganisms, fungicides, and herbicides.

Consequently, artificial seeds can be used as an alternative to vegetative propagation for cloning of selected individuals or for propagation of costly and scarce hybrid seeds.

The major drawback of artificial-seed technology is cost. This is related to the fact that all work has been carried out at a research and development level. To my knowledge, artificial seeds have not been used on a commercial scale with any species. Apart from prohibitively high costs, the use is limited to plant species with a well functioning system for micropropagation by somatic embryogenesis. Therefore, for most commercially important plant species, improvement in micropropagation protocols are needed before artificial seed technology is possible. An additional disadvantage has been the low desiccation tolerance of the encapsulated hydrated seeds. To prevent desiccation it has been necessary to cover the somatic embryos with a polymer. However, this requirement has led to an oxygen deficit within the artificial seeds and a short storage life of the product.

EXAMPLES OF ARTIFICIAL SEEDS

The species that one could imagine using for artificial seed production are crops with a high value such as cut-flower species, ornamentals, and vegetables. In addition, artificial seeds can be integrated into breeding programs for clonal propagation of hybrid seeds, transgenic plants, or other highly bred plants (Redenbaugh et al., 1988). To be able to use artificial-seed technology with a plant species there is a requirement for a commercially feasible micropropagation system. Table 1 shows the species where germination of artificial seeds has been achieved aseptically on nutrient media in petri dishes and under nonsterile conditions in soil (Redenbaugh et al., 1991).

Table 1. Species with artificial seeds.

Aseptic germination in petri dishes	
Celery	Corn
Cabbage	Sweet potato
Carrot	Eggplant
Cotton	Eucalyptus
Alfalfa	Norway spruce
Rice	Mulberry
Lettuce	Sandalwood

Germination in soil under nonsterile conditions
Celery
Carrot
Alfalfa

Alfalfa has been used as a model species. This is primarily because of the well developed micropropagation system and because alfalfa has exalbuminous seeds—seeds without an endosperm. Therefore, the nutrients necessary for germination are present in the embryo itself. The potential use of synthetic seed technology for alfalfa has been to clone hybrid seed and make them available to farmers. In this way, the time necessary for propagation of the hybrid seed can be shortened considerably while the genetic superiority of the hybrid seeds is maintained (Redenbaugh et al. 1988).

Mature somatic embryos of alfalfa have been encapsulated in an artificial endosperm of alginate and coated with a polymer to reduce the tackiness of and water losses from the artificial seed. This allows the artificial seeds to be handled like normal seeds and be sown mechanically. Field trials have shown that the artificial seeds need to be protected by a plastic polymer to obtain a reasonable frequency of embryo to plant conversion. Naked, pregerminated embryos have also been transferred to field conditions and show at least the same survival as artificial seeds (Fujii et al., 1992). In an experiment with automated encapsulation of somatic embryos the costs of artificial seeds have been estimated at 7¢ per artificial seed and 56¢ per plant in the field produced in this way (Redenbaugh et al., 1991). Further

reductions in costs can be envisaged with commercial-scale artificial-seed production. Still, these prices are very high compared to the price of alfalfa seed, but the prices can be considered typical for a plant species with a micropropagation system of comparable quality. Bearing this in mind, the time when artificial seeds can compete with normal seeds is close for high value crops.

In the Botanic Garden at the University of Copenhagen, we have been working with somatic embryogenesis in *Picea abies* (Norway spruce), *Picea sitchensis* (Sitka spruce), and *Abies nordmanniana* (Caucasian fir or Nordmann's fir). In both spruce species the mature somatic embryos we can produce germinate and develop into plants at reasonably high frequencies. We have tried to encapsulate mature somatic embryos of Sitka spruce but have only achieved sporadic conversion. However, a recent report showed a 90% germination frequency of Norway spruce artificial seed under aseptic conditions (Fourré et al., 1991).

In Nordmann's fir, which is used for Christmas tree production, the micropropagation system is not of the same quality. We are only able to regenerate a low number of mature somatic embryos per petri dish and the germination capacity is not very high. On the other hand, Nordmann's fir is a high value crop in which the interest in using artificial seeds is very high.

CONCLUSIONS

During the past years there has been a marked improvement in the micropropagation systems in a number of plant species and the quality of mature somatic embryos is getting closer to that of zygotic embryos. In addition, considerable progress in the desiccation tolerance of mature somatic embryos has been obtained and this opens possibilities for production of artificial seeds which can be dried and stored. Unfortunately, most research with artificial seeds has been done with embryos that are not dormant, do not tolerate desiccation, and cannot be stored. Therefore, the storage life of the product (the artificial seed) is very short and usability limited.

The ideal product is an encapsulated embryo, that can be stored in a dormant stage. Whether or not the embryo is desiccated is of minor importance. The major point is that it has some storage life. Apart from being dormant the artificial seeds also should have a high germination frequency—even after storage—in the field or greenhouse.

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Challenges and Opportunities for Plant Propagation in a Changing World

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The environment in which we do our research or propagate plants has changed dramatically in the past 25 years. It is critical that we appreciate the nature of those changes and how they are influencing our research agenda and our businesses.

At one point in our history we were pretty much left alone to pursue scientific inquiry or conduct our business as we wished. But now many people and groups have an interest in setting our agenda. Let me give some examples based on the 2½ years I spent in Washington, D.C. as Assistant Secretary for Science and Education. As we establish the challenges, I will suggest plans of action, so we can anticipate and plan ahead.

The U.S. agricultural system is viewed by the world as one of the outstanding products of American ingenuity. In 1950, one American farmer produced food and fiber for 27 people; in 1990, the production was for 128 people. This increased efficiency has been passed on to the consumer in the form of lower food costs. In 1950, the average consumer spent 21% of his/her disposable income on food. In 1990, the figure was one of the world's lowest—11.8%. In addition, agricultural efficiency has made the United States a strong competitor in international trade. Agricultural exports represent one of the few segments of our economy in which there is a favorable balance of payments.

How were these achievements made possible? In the period of U.S. history following World War II, the power of science was harnessed to give agriculture a dramatic boost in productivity. Through a combination of genetic improvement, the application of fertilizers, and the use of chemicals to control insects, diseases, and weeds, agriculture achieved striking increases in yields. In the field of plant propagation new technologies were introduced. Plant growth regulators were discovered and used to speed and extend the range of plant material propagated from cuttings. Mist propagation extended the range of plants propagated from cuttings even more and reduced cost of production. Tissue culture facilitated clonal propagation of plants, and now molecular biology or biotechnology is providing new tools to understand plant growth and development, such as juvenility and the process of root initiation as well as to exchange genetic material in a way and with a precision that was not previously possible.

But that was in simpler days, when the goal was merely to produce enough food, fiber, and plant material and to deliver them to the consumer. Today's agriculture is being required to fill many roles and meet many obligations. In the 1990s, agriculture is being asked to play a major role in preserving our environment, increase food safety through the use of fewer chemicals, provide jobs in rural areas, maintain international competitiveness in the presence of free trade agreements, and feed a growing population on an ever-decreasing area of cultivated land. For example, the USDA's Economic Research Service states that by 2010 world

population will reach 7.5 billion people, and just to maintain current caloric intake on a world average food production will have to increase by 40%.

EXTERNALITIES

Over the years, I have concluded that if we truly want to understand the forces at work in motivating agricultural policy, we need to go beyond a simple preoccupation with the technology and science involved or with our day to day business operations. There are powerful forces—what economists call "externalities"—which supersede the control of individuals and even of institutions. These externalities affect not only the way in which we do our work, but what work we decide to do. For example, our agricultural research policies are not formulated in any pure and solitary test tube. They spring from the messy and often disorderly real world of conflicting demands and unclear choices.

Agriculture can no longer operate—in fact, we probably never really did—in isolation from an increasingly concerned public. Our course is continually influenced by the changing winds of public opinion and national policy.

Some 40 years ago, when a national farm bill was formulated, there were fewer players, only three or four major groups were involved. Now, someone counted over 215 groups with active interests that are making their voices heard and are shaping policy. To give you an idea of the complexity of the issues involved, the 1990 Farm Bill is the largest piece of legislation ever passed by Congress—719 pages long! When the President signed the bill, he said to Clayton Yeutter, then Secretary of Agriculture, "It's all yours....if you can carry it!"

Maybe we don't necessarily need to learn any more about agriculture per se, but we may need to learn more about the world outside of agriculture and how it affects us as reflected in the attitudes and opinions of the public—and by extension, Congress. My point is that we in agriculture must keep many different public and congressional priorities, needs, desires, and concerns in mind—<u>and</u> work to make <u>them</u> more aware of <u>ours</u>. We need to make clear that we benefit society—even beyond providing the basic necessities of food, fiber, and environmental enhancement—and that we can help it meet many of the crucial challenges of our times.

COMPETITIVENESS

And what exactly are some of those challenges? Just look at the headlines in the newspapers. For example, the current focus in the public and in Congress on the importance of international competitiveness and the U.S. trade deficit. These concerns are pushing agriculture to reduce production costs and enhance product quality, and are driving agricultural research to find the best ways to do that. In order to maintain our competitiveness in a tough global marketplace, and at the same time have environmentally sensitive agriculture, we need every ounce of careful management and efficient technology we can muster.

We also need to adjust to shifting consumer trends and demands. Through research, we can develop agricultural products which are less expensive, more appealing to consumers, and more nutritious. Demands change constantly. Look at the grocery store shelf space now devoted to oat and rice bran, dietary fiber products, and lowfat milk. You have to hunt for the whole milk these days!

Agricultural researchers need to join with nutritionists and physicians to study the questions of diet and health. Do cole crops prevent cancer? If so, is it because

of Vitamin E? Or something else? With some hard data, we might even be able to convince President Bush to eat broccoli. Closer to home is the ovarian anti-cancer drug, taxol, extracted from the bark of *Taxus* trees.

ENVIRONMENT

The environment is another major area in which the overall national agenda is influencing agriculture. Environmental concerns were strongly reflected in the sodbuster and swampbuster provisions of the 1985 Farm Bill—and they are even more strongly present in the 1990 Farm Bill. The swampbuster, or wetlands, provisions are among the most controversial, particularly when there has been a lack of agreement on the definition of "wetlands."

As I mentioned earlier, through technology, the United States has developed the most efficient food, fiber, and forest system in the world. But we now recognize that the technology which helped bring that about has had some costs which were not fully anticipated at the time of its introduction.

As science has fine-tuned its instrumentation and its abilities to track and detect smaller concentrations of contaminants in our food, our ground water, and our environment, the public is becoming more and more sensitive to the social, environmental, and health implications of agriculture—and more and more vocal about them. Research must now help agriculture respond to these legitimate concerns.

It is time for those of us in agriculture to be proactive rather than defensive. Not only does our future ability to produce food and fiber depend on it, but to do otherwise is to invite restrictive legislation and regulation which may remove our decision-making power and constrain our flexibility to adopt management practices which best fit each farming situation. There is the feeling among some that agriculture must be regulated into environmental concern. This is not the case—nor would it be in the best interest of our nation.

GLOBAL CLIMATE CHANGE

But there are other concerns about agriculture and the environment. Soil erosion is an old problem that is still with us, while newer issues include greenhouse gases which may contribute to global climate change. Although there is continuing debate about whether the accumulation of greenhouse gases will actually lead to global warming, there is general agreement that we should explore ways to reduce emissions and to sequester the carbon dioxide already in the environment. Agriculture has three major roles to play in global change.

First, it generates greenhouse gases, albeit a relatively small percentage in relation to carbon dioxide released in the production of electrical energy. Agriculture's contributions to greenhouse gases are methane and nitrous oxide which trap 20 and 290 times more radiant energy respectively than carbon dioxide. When expressed in carbon dioxide equivalents, rice cultivation contributes 2,300 metric tons per year or 7% of the greenhouse gases; ruminant animals, 1,500 metric tons per year or 5%; and nitrous oxide from nitrogen fertilizer, 440 metric tons per year or 1%. Thus, all the greenhouse gases from agriculture represent 13% of those emitted each year. By comparison, globally, commercial energy production is 18,800 metric tons per year, or 57% of the total greenhouse gas emissions.

A second role for agriculture in global change research is to genetically modify

plants and animals so that they may adapt if there is climate change. Conventional plant and animal breeding has been used for years to extend the range in which crops and animals can be raised. When red wheat was first introduced into the midwest, its range was limited. Plant breeding to adapt the wheat to other climates dramatically extended the area in which it is grown. In fact, the geographical range is now so large that the average temperature variation is over two degrees Fahrenheit, equivalent to the temperature increase predicted in some global climate change models.

The new tools of molecular biology are enabling us to explore the mechanisms by which plants survive temperature stress, drought, and salty conditions. This ability may become even more important as we get a better understanding of the potential impacts of global climate change — it is already relevant in areas of this country, and in nations that experience droughts and other climate extremes.

The third and very beneficial role for agriculture and forestry is in sequestering and recycling carbon dioxide through the process of photosynthesis. This was the basis of the President's "America the Beautiful" program, designed to plant a billion trees a year. In addition, there is renewed emphasis on the production of energy from biomass.

Although interest in this area of research peaked in the 1970s at the time of the first energy crisis, there are three good reasons to believe that a more sustained effort is developing:

1) The experience in the Persian Gulf has reemphasized the need to reduce our dependence on foreign energy sources and, in the long term, to find alternatives to fossil fuels.

2) The President's Clean Air Act requires the use of more oxygenated fuels in cities that have failed to meet EPA clean air standards. Ten percent ethanol in gasoline can reduce carbon monoxide output by 20% to 25%.

3) Finally, producing energy from biomass rather than from fossil fuels recycles carbon dioxide rather than adding it to the atmosphere.

Today, the U.S. average for carbon dioxide emissions is the equivalent of 19.4 metric tons of carbon dioxide per person per year. The average for Great Britain is 9.9 and for China 2.1. Clearly, if we are to at least maintain current standards and at the same time help developing nations achieve similar living standards without overwhelming the atmosphere with carbon dioxide, we must conserve energy and develop alternative energy sources, including biomass.

Researchable areas include crops developed specifically for energy production, increased photosynthetic efficiency, better conversion of biomass into energy, and improved methods of separating ethanol from water. Successful research in this area includes a recent report that a genetically modified microorganism can hydrolyse cellulose into sugars and then ferment the sugar into ethanol. But this is also an area of great potential for the nursery industry. Trees used in the urban and suburban landscape not only fix carbon dioxide, but they provide shade and cooling through transpiration. Since conservation of energy can be one of the most cost effective ways of reducing carbon dioxide emission, we as an industry can help achieve the country's goals by providing the trees used for shading of buildings and other facilities such as parking lots which act as heat sumps.

SUSTAINABLE AGRICULTURE

The goal is for agriculture to operate in an environmentally responsible fashion, while continuing to produce both economically and profitably. Sustainable agriculture is the use of the very best of technology in a balanced, well-managed, and environmentally responsible system. This includes using our newest scientific tool, biotechnology, to move genes precisely and quickly to create plants that are genetically resistant to disease and pests and therefore require fewer chemicals in their production.

As we learn more and more about the processes and materials involved in animal and plant life, we can ask—and answer—questions that weren't even possible before. Everywhere you look, there are exciting things going on. This is not pie-in-the-sky science; we are very close to application, e.g., BT gene in tomatoes and cotton and the use of antisense gene technology to modify the ripening process in fruits and vegetables.

WATER QUALITY

One of the reasons that sustainable agriculture is coming to the fore is a very real public concern over reports of contamination of the nation's ground and surface water resources by agricultural chemicals and nutrients.

In response, the USDA has identified protection of the nation's water resources as a high priority. It has made it clear that farmers need to be involved in a vigorous effort to protect both ground water and surface water from contamination as a result of their land management practices.

Our incredibly low food costs are very dependent on the use of technology—including important pesticides and fertilizers. Technology also includes increased emphasis on Integrated Pest Management (IPM)—getting the best use out of all the control strategies available: genetic resistance, biological control, cultural practices, and precision application of pesticides. We want to develop new systems of control and speed the adoption of existing programs.

These are often under the umbrella of Integrated Resource Management (IRM)—a systems management approach which looks at the farm as a whole. We can increase efficiency by cutting production costs and protect the environment by optimizing chemical usage.

Not only our economic welfare, but also the quality of our lives depends on our ability to develop agricultural systems which produce efficiently while sustaining our natural water resources. A proactive program to address real and perceived impacts of agricultural technology on the environment is a far better alternative than a regulatory program which could reduce competitiveness and unnecessarily increase the cost of agricultural commodities. For example, in the nursery industry we have to be sure that the public is aware that we are addressing issues such as run-off from container operations by exploring the possibilities and problems of recycling irrigation water.

FOOD SAFETY

In addition to water quality, many Americans are tremendously concerned about the safety of the food they eat. According to a recent national survey of over 900 households by the Environmental Protection Agency (EPA) and the Michigan Agricultural Experiment Station, 28% of the respondents ranked pesticide resi-

dues as the "most serious" food safety issue. And 25% thought that the risk of health problems from pesticides was as high as one in a hundred! This is so far from reality!

While every reasonable care should be taken to protect consumers, the balance between risk and safety unfortunately has sometimes tipped too far in one direction, leading to the belief held by some that any risk, no matter how small, is totally unacceptable. Look at the outcry that arose when the EPA invoked a "negligible risk standard" for agricultural chemicals in food—and we're talking about a one in a million chance over an entire lifetime.

The perception of chemical residues on food items, especially fresh fruit and vegetables, has caused widespread public alarm and major disruptions of markets. Remember how the outcry over Alar caused some supermarket chains to refuse to sell an otherwise desirable crop?

Agriculture must communicate to the public that we do not live in a totally risk-free environment—that you are infinitely safer eating fruit and vegetables than riding in a car. Again, we need to stress the fact that our incredibly low food costs are very dependent on the use of technology—including pesticides and fertilizers.

We also need to emphasize the positive effects of agriculture, especially fruits and vegetables—so well-produced here in California—on human health. Vitamins from fruits and vegetables reduce cataracts; anti-oxidants prevent cancer; and dietary fiber helps control cholesterol. In a recent article in the International Herald Tribune there was a discussion of the role of vitamins such as beta carotene and E in reducing cholesterol accumulation and thus reducing the potential for heart attacks and strokes, even though the blood cholesterol level is high.

PUBLIC PERCEPTION OF TECHNOLOGY

There is one further challenge I want to share with you before I close: my personal—and professional—concern over the growing anti-science, anti-technology attitude of much of the general public. The scientific freedom of inquiry is under the threat of becoming an endangered species!

It is ironic that some of the best new tools we have in agriculture to help address the challenge of feeding and clothing a growing world population on a finite amount of land in an environmentally sensitive manner are being attacked under the banner of environmental, economic, ethical, and social concerns.

For example, with all the possible benefits of biotechnology, anxiety on the part of a worried public still exists. And unfortunately, that anxiety is often based upon the perception of risk rather than the reality.

To my mind, this is one of the single most critical issues confronting us today. Let me quote a January (1/7/91) editorial in the Wall Street Journal: "No modern advance is more vulnerable to damaging public assault today than agricultural biotechnology. It promises to produce a more bountiful, cheaper food supply. But for years the promise has had to confront demagogic scaremongering about the science itself, which in turn frightens consumers, which in turn causes not-very-courageous supermarket executives to repudiate the new technology." Last August a group of New York chefs announced they would not prepare or serve genetically engineered vegetables.

Another example is herbicide "safened" plants. There was an attempt during the debates on the 1990 Farm Bill to ban publicly funded research on herbicide

resistance. The rationale was that such research could lead to an increased use of herbicides. This approach is wrong for two reasons. First, the presumption is wrong. Herbicide-resistant plants will not lead to the use of more herbicides, but rather to the use of environmentally safer herbicides. Actually, less of the herbicide may be used because the herbicide can be applied directly on the "safened" plants after weed competition becomes a problem rather than using them as a prophylactic control. Second, restricting research will diminish the possibility of discovering better ways to control weeds which are both effective and environmentally safe.

Social, ethical, environmental, and economic impacts of new technology are valid issues, but they should be approached by science-based research, not emotion-based regulation.

Some people seem to forget that the ultimate beneficiary of research and technology which increases food production efficiency is the consumer—in other words, all of us—who enjoy inexpensive, wholesome, and safe food which can be produced in a way that is environmentally sound. As the Wall Street Journal concludes, "Better achievements are still to come—if the public and policy makers are willing to stand up to the scaremongers."

My own experience has been that the more people understand about science and agriculture the more they are interested in pursuing it and feel positive about the work it is doing. If agriculture is to be able to continue to use technology to improve itself and our overall quality of life, we must increase general scientific literacy, and make our case in the court of public opinion. This challenge is becoming more critical as society becomes more urbanized. People lose touch with the knowledge of the source of their food and fiber and the important role agriculture plays in the economy.

CONCLUSIONS

As change breeds challenge, agriculture must not only respond, but must anticipate and lead the way. The agricultural sciences and agribusiness will play a central role in meeting the challenges I have mentioned today.

Clearly, from ancient civilizations to our current technologically advanced society, national leaders have understood that new scientific knowledge can be a tremendous instrument of national strength and public good. The great British leader Winston Churchill said, "If the human race wishes to have...prolonged... prosperity,...science will do for them all they wish and more than they can dream." However, we can no longer take that support for granted. In addition to research and teaching, we must continue to communicate with the public and the policy makers about how our research benefits them and the quality of their life. This is an essential responsibility if we are to compete effectively for public funds to support research.

Thank you for the opportunity to share these thoughts with you. I see a very challenging, but nevertheless very rewarding, future ahead for all of us in agricultural research.

Propagation by Root Cuttings

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In the age of high technology it is sometimes refreshing to remind ourselves that old propagation techniques may still have commercial if not experimental application to today's nursery production. It was with this in mind that we decided to try root cuttings for the more difficult to propagate rootstocks and cultivars we grow on our nursery. We produce fruit and ornamental trees and clonal rootstocks by traditional field production. The various subjects chosen were: M.9 apple rootstock, pixy plum rootstock, and own-root apple cultivars.

SOURCE OF PARENT MATERIAL

The age of the plant from which root cuttings should be taken is very critical. Too young and thin and the material does not hold enough reserves to survive the early growth phase, too old and they will not produce shoot initials readily. Our experiments showed that cuttings 10 to 15 cm long and at least 10 to 15 mm top diameter at the proximal end were most suitable and in sufficient number. One-year trees (2- to 3-year root system) provided the most successful results and were readily available.

COLLECTION

The timing of collection has to coincide with tree lifting in the early autumn. Roots also have at that time their highest concentration of photosynthates. As the trees are pulled from the ground ready for bundling, roots are selectively removed making sure no more than two are taken per tree. They are then kept moist, dipped in fungicide, boxed, drained to being damp rather than wet, and cold stored at 0°C until March.

PREPARATION

Whole roots are bundled with elastic bands, cut to size with a band saw, checked for freshness and any fungal infection, and prepared for planting.

PLANTING

It is important to prepare a suitable compost medium of 70% peat, 20% bark, and 10% grit, with additional slow-release fertiliser, etc. A raised bed is ideal, preferably in a polythene tunnel, outside if possible, but later planting would be necessary with some short-term laid-on protection at night or during cold weather.

Roots are planted upright (care must be taken here!), with the tops of the roots at ground level. Spacing will depend on the plant size requirement after one season's growth. We experimented with spacing from 6 × 2 cm to 10 × 4 cm. The close spacing was adequate to produce straight growth and enough competition for only one shoot per root to become reasonably dominant. The wider the spacing the larger the eventual plant but often with 2 to 4 shoots per root. This may well be desirable in shrubby plants, so spacings can be varied by experience.

Timing of planting is critical. Too early, when ambient temperatures and compost are cool, can cause some rotting of cuttings. Direct planting out of cold storage in late March is ideal with rapid root initiation from callus tissue nodules. A deep compost bed provides even moisture levels which are important during early growth.

Other subjects, all of which have produced variable results in the past, are likely candidates for this propagation technique. They are as follows: *Acer*, *Betula*, *Aesculus*, *Syringa*, *Prunus*, and *Corylus*.

Cutting Propagation of *Chamelaucium* Cultivars

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INTRODUCTION

The genus *Chamelaucium* is endemic to Western Australia and consists of 12 species of small- to medium-sized shrubs. The foliage of most species is xerophytically adapted to a needle shape and it forms a soft green backdrop to the flowers. The genus is principally cultivated for its flowers which are 1 to 2 cm long, five-petalled, and waxy in texture. The main flowering period is winter and early spring. The waxy nature of the flowers has given rise to the common name "waxflowers" for this genus. This genus has a requirement for very sandy, well-drained soils in an open, sunny position.

The best known member of the genus is *C. uncinatum*, the Geraldton waxflower from the Geraldton district of Western Australia. It is popular as a shrub for cut flower use. It is widely used as a flowering garden shrub, but it is very short-lived if soil type and drainage are unsuitable. In addition, it is also popular as a flowering specimen for growing in tubs on patios, etc.

Chamelaucium uncinatum grows to a height of around 3 metres and forms a broad, spreading habit. Flower size is large and a number of colour forms have been selected for cultivation including: 'Alba', 'Fortune Cookie', 'University', 'Purple Pride', 'Burgundy Blush', 'Mullering Brook', 'CWA Pink', and 'Early Hard Pink'.

Chamelaucium floriferum is another highly ornamental waxflower species; it has a proliferation of small, white flowers and in the early years the shrub has a conical growth habit which is densely compact in habit. This growth habit lends itself well to use as a garden shrub or as a patio specimen; it is not so useful for cut flowers. In the natural habitat *C. uncinatum* and *C. floriferum* tend to hybridize freely and a number of *C. floriferum* × *C. uncinatum* hybrids are in cultivation. The most widely cultivated of these in Queensland is 'Lady Stephanie', a late flowering light pink form which is widely used by cut flower growers. Another *C. floriferum* × *C. uncinatum* hybrid with similarities to 'Lady Stephanie' is the 'Wanneroo Wax'.

Chamelaucium ciliatum is a more compact species growing to about 1 metre high. It has small heath-like foliage and the flowers have a bicolor effect of white with some red on the outer petals. This species also has given rise to many selections, and the form 'Stirling Range' is more compact and floriferous and makes a very attractive pot plant or garden shrub.

Chamelaucium megalopetalum is a genus with larger flowers. It appears to hybridise freely with other species in the wild and a number of selected megalopetalum hybrids with much larger flowers are now coming into cultivation. These are showing great potential for the cut flower trade.

THE UNIVERSITY PLANT NURSERY UNIT

The University of Queensland's Gatton College operates a plant nursery unit as a part of its field facilities unit for teaching. The philosophy of this unit is to carry out

teaching within a commercially successful operation. In order to achieve commercial success it has been necessary to select a number of species of plants and develop production systems which can ensure the production of high quality plants. The genus *Chamelaucium* is one of those commercial plant lines which the UQGC plant nursery has concentrated on for a number of years.

This particular genus is in wide demand from both the local Queensland cut flower industry and from the ornamental nursery industry. Surprisingly, few nurseries in the local area grow this genus; it is considered difficult and unreliable in its propagation and the maintenance of stock plants for cutting propagation in Queensland is quite difficult. There are a number of commercial waxflower plantations in close proximity to Gatton College and most cuttings used for our propagation programs are collected from vigorously growing plantation plants. This eliminates the need to establish mother stock beds in the nursery unit.

THE GERALDTON WAXFLOWER FLOWERING SEASON

The southern hemisphere flowering period for waxflowers extends from April to October (autumn to spring) so the main cutting propagation period for the crop occurs outside of this period. After harvesting is complete, regrowth shoots must be allowed to develop to a level of maturity suitable for adventitious root growth to occur. Very soft and succulent shoots are difficult to root as they tend to desiccate very rapidly after collection. Shoots which are allowed to develop to a semi-ripe condition prior to collection will perform much more successfully. Therefore, the propagation season for waxflowers at Gatton does not commence until mid-late November when growth of the early flowering types is suitable. These early flower types include *C. uncinatum* cultivars such as 'Early Pink', 'CWA Pink', and 'Early Hard Pink'

Propagation of the later flowering types such as 'Lady Stephanie' and *C. floriferum* does not commence until late January. The propagation program will then continue through until April when flower bud initiation terminates the season. Some of the later flowering cultivars can be propagated through to late May before flower bud initiation occurs.

PROPAGATION

Type of Cutting. Terminal stem cuttings 8 to 10 cm long are preferred and the growing points are left intact. Cuttings are collected from the stock plants and placed in polystyrene containers to prevent desiccation until they are brought in from the field.

All cutting material is routinely dipped in a 2% solution of sodium hypochlorite to eradicate any fungi or bacteria which may be present on the leaves. This also helps to reduce leaf tissue temperature and maintains the cuttings in a moist condition until they are trimmed. Cuttings are trimmed using sharp secateurs and the needle leaves are stripped from the basal 2 cm of stem. This enables easier sticking of the cuttings and provides better root development.

The Propagation Medium. The propagation medium used as standard consists of 1 sphagnum peat (New Zealand origin) : 1 perlite : 1 vermiculite (by volume). This is a very high quality medium with little risk of pathogen problems and this eliminates the need to pasteurise the medium. The air-filled porosity of this mix is

in excess of 40% and it performs well with most stem cutting propagation.

The Propagation Container. Cuttings are direct stuck into Jiffy strips (Jiffy 515) which are imported into Australia from Denmark. The Jiffy Strips are placed in wire trays for unitisation and this produces a unit of 176 containers. Jiffy Strips are used for most of our cutting propagation as we feel that they encourage the development of a more fibrous and branched root system and they reduce the problems associated with handling of small rooted cuttings.

Thorough soaking of the Jiffy Strips is essential prior to filling with propagation media, otherwise the peat walls of the container may not be adequately wetted. This can lead to problems with root penetration as the root system on the cutting develops. It is also important in the routine management of Jiffy Strips to water regularly to prevent drying of the container walls. If they are allowed to dry out during root development the roots may be inhibited in their outward growth through the walls of the container.

The Propagation Environment. Waxflower cuttings are propagated in a fibreglass-covered greenhouse using a high-pressure fogging system for humidity control. The greenhouse is heavily shaded through the summer propagation period to provide approximately 80% shade. The fogging system is set to maintain a minimum 85% humidity in the greenhouse atmosphere. A warm-water bench heating system is installed and a root zone temperature of 25°C is maintained for most of the year. Through the main summer period the ambient greenhouse temperature is considered adequate for propagation and the heating system is not used during December, January, and February.

The fogging system provides a means of accurate humidity management but it does not apply sufficient water to maintain moisture levels in the propagation medium and hand watering is carried out as necessary to ensure that the medium and the Jiffy Strips do not dry out.

Auxin Treatments. The most successful auxin treatment for *Chamelaucium* cultivars at Gatton College has been IBA disolved in liquid at 2000 ppm. The commercial product used (Rootex L) has ethanol as the solvent and it has been suggested that the ethanol may cause burning of the stem tissue at the base of the cuttings. Earlier this year trials were undertaken to compare IBA disolved in ethanol and IBA disolved in potassium hydroxide across a range of *Chamelaucium* cultivars. The IBA with ethanol gave consistently higher strike rates across all cultivars.

Rooting success rates vary with cultivar and time of year. Examples of the strike rates achieved at Gatton College during the 1992 production season were:

'Chinchilla Pink'	92%
'Fortune Cookie'	88%
'Lady Stephanie'	71%
'Purple Pride'	94%
'Wanneroo Wax'	82%

The New South Wales Department of Agriculture undertook a waxflower breeding program during the late 1980s and the rights to a number of the cultivars

developed in this program have been sold to industry. Gatton College has been propagating a number of these cultivars on behalf of the company which holds the rights and the propagation strike rate for a number of cultivars has been high. It is likely that these cultivars will become available to industry after plant variety rights have been granted.

Propagation Time Scale. Root development is normally well advanced in most waxflower cultivars after 4 to 5 weeks and all cuttings are normally weaned at the 6-week stage. The rooted plants in the Jiffy strips may then be handled in a number of different ways:

1) The rooted cuttings may be sold in the Jiffy containers to flower growers for field planting. It appears that small, vigorously growing plants straight from propagation will establish in the field better and with fewer root problems than larger container grown plants.

2) The cuttings in the Jiffy containers are potted into square liner pots (50 × 50 × 125 cm) called native tubes to grow on to a larger size prior to planting in the field. Root development in these liner pots can be very vigorous and if the plants are not planted out at the optimum time, serious root malformations may occur. Over the last 12 months trials with copper compounds for root growth control have been undertaken at Gatton and we feel that this treatment will be highly beneficial for waxflower plants grown in these liner pots.

3) The rooted cuttings may be potted on into 140- or 200-mm pots for the retail nursery trade and grown on in the nursery unit until flowering is well advanced before delivery to the retail outlets.

CONCLUSIONS

The production of waxflower plants in the Gatton College plant nursery has been undertaken for a number of years. During that time a number of problem areas such as auxin treatments, propagation media and environment, propagation containers, and root growth have been investigated to enable the plants to be produced more efficiently. A large number of trade customers, including flower growers, wholesale nurseries, and retail garden centres, are supplied with plants. Commercial production of this type allows our students to be closely associated with the commercial realities of the nursery industry and allows the College to maintain very close links with the local nursery industry.

Towards 2000—Development and Propagation of New Plant Material

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We need plants in our gardens and cities for food, beauty, and health. It's a green revolution and our I.P.P.S. Society is vital to that revolution, without plant propagators it can't happen.

To this end, keen plants people all around the world are becoming hungry for new plant material as well as reintroducing the old. New plants are developed by: research, breeding, mutation and sports, radiation, and gene splicing. Old plants are reintroduced by: reintroduction in a new mode, using chemical retardants, using chemical enhancers, elimination of viruses, and clonal selections.

As a grower you may be blessed with a once in a lifetime find. But if you live long enough and are super sharp, you may be lucky enough to find more in a lifetime. My nursery has introduced a number of sports and I will outline the development and propagation of three of our best introductions.

***Cupressus arizonica* 'Blue Ice'**. I found this cultivar as a chance seedling among a line of shelter trees growing in our nursery beds in the 1960s. This plant stood out from the rest with its ice blue look. I put it under glass in a 2-gal container. Cuttings were taken in February 1961, dipped in 8,000 ppm IBA, and set in a pumice and peatmoss medium (8 : 2, v/v) bottom heated to 20°C. The cuttings were propagated on a dry/wet cycle, keeping the wound dry until a good callus had formed and then increasing the mist to induce rooting but avoiding too much wetting of the basal area to prevent rotting. Weekly applications of Captan and Topsin were used as a preventative spray. First rooting showed in September (spring) 1961. Twenty rooted cuttings then became the base of the initial stock plants for the half million liners I have produced to date. It is very important to keep stock of this cultivar juvenile. Cuttings from plants more than 3-years old become very difficult to root. 'Blue Ice' is very tolerant of dry conditions. Its attractive silvery foliage and conical shape makes for a superb large specimen conifer as well as being ideal for hedging and shelter belts.

***Pittosporum tennuifolium* 'Silver Magic'**. This is one of our choice New Zealand native cultivars prized for garden backdrops, hedging, and cut foliage. It was found as a sport in our nursery on *P. tennuifolium* 'Silver Sheen' as one small variegated branch of three cuttings. These were rooted in a shade tunnel under intermittent mist with a pumice and peatmoss medium (8 : 2, v/v) bottom heated at 15 to 20°C. The secret to rooting pittosporums, as with most New Zealand natives, is a well-drained mix, and top temperature below 20°C maximum to avoid leaf drop. Cuttings taken in June (winter) are rooted by September (spring). Three cuttings were the basis for one of our most popular native lines. It is interesting to note that sporting occurs quite regularly in *Pittosporum* cultivars, and hard pruning seems to induce reverse colour breaks.

***Lysimachia* 'Sunbird' PVR**. The initial cultivar from which this plant originated was of German origin, with my initial stock imported from Outeniqua Nursery in Australia. After establishment of this initial crop, I noticed that one plant had developed a small pink splash on a leaf. I cut the stem of this back to the crown and rooted it in a peatmoss and pumice medium (1 : 1, v/v). When the rooted cutting had a good root system, I took the tip with the variegation and rooted it. The resultant shoots from the underground node produced a more uniform variegation. From then on I continued to work on the plant and selected better variegations as they appeared from each group of cuttings. A year of persistent selection resulted in a stable variegation. Thus was *Lysimachia* 'Sunbird' borne.

'Sunbird' is a unique variegation of green, and cream to brilliant pink, with yellow flowers making it an attractive groundcover, patio, or hanging basket plant.

Site of Action of Auxin in Adventitious Root Initiation

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INTRODUCTION

It has been shown many times under controlled conditions that auxins are the applied phytohormones which consistently enhance adventitious root production. Indeed, research has shown that division of the root initial cells is dependent upon either applied or endogenous auxin (Hartmann et al., 1990.) However, knowledge of the mechanism of auxin action in adventitious rooting remains an enigma although auxin was identified as a root-forming substance as early as 1934 by Thimann and Went. This paper deals with experiments performed in our laboratory on the regulation of adventitious root initiation in mung bean [*Vigna radiata* (L.)R. Wilcz.]

MATERIALS AND METHODS

Plant Material and General Procedures. Mung bean seeds were surface sterilized in 10% Clorox (v/v) for 10 min and rinsed in tap water. After aeration for 24 h in tap water, they were sown 1 cm deep in plastic trays containing perlite. The growth room was maintained at 26±1°C. A 16-h photoperiod was supplied at a quantum flux density of approximately 205 $\mu E\ m^{-2}\ s^{-1}$.

Uniform cuttings made from 9-day-old seedlings were placed in sterilized distilled water prior to use. Each cutting consisted of a 3-cm hypocotyl, the epicotyl, two primary leaves, and the apical meristem. Ten cuttings were placed in a 19 × 65 mm shell vial containing 1 ml of the treatment solution. After uptake of the various solutions (approx. 2 h), distilled water was added to the cotyledonary node and maintained at this level for the duration of each experiment.

DISCUSSION

Research Suggesting Direct Interaction Between Auxin and DNA During Adventitious Root Initiation in Mung Bean. As mentioned above, auxins appear to be the phytohormone that consistently stimulates rooting (Fig. 1). In mung bean, the synthetic auxins IBA and NAA effectively promote adventitious root formation between a concentration range of 10^{-7} and 10^{-3} molar (Geneve and Heuser, 1982); 2,4-D is less active than the other auxins tested while IAA, the native auxin, is not as active as NAA and IBA possibly because IAA is metabolized (Hess, 1965) or converted to various conjugated forms (Norcini and Heuser, 1985).

In normally-developing, intact, mung bean hypocotyls, the pericycle cells are the site of adventitious root initials. These are the cells (referred to as "rooting-zone parenchyma" [R-ZP]) receptive to the auxin. As a result of cutting, these R-ZP cells are transformed from quiescent parenchyma cells into cells that give rise to the roots. Blazich and Heuser (1979) observed histological changes of the root initial cells during root formation in mung bean cuttings. They noticed that the nuclei and

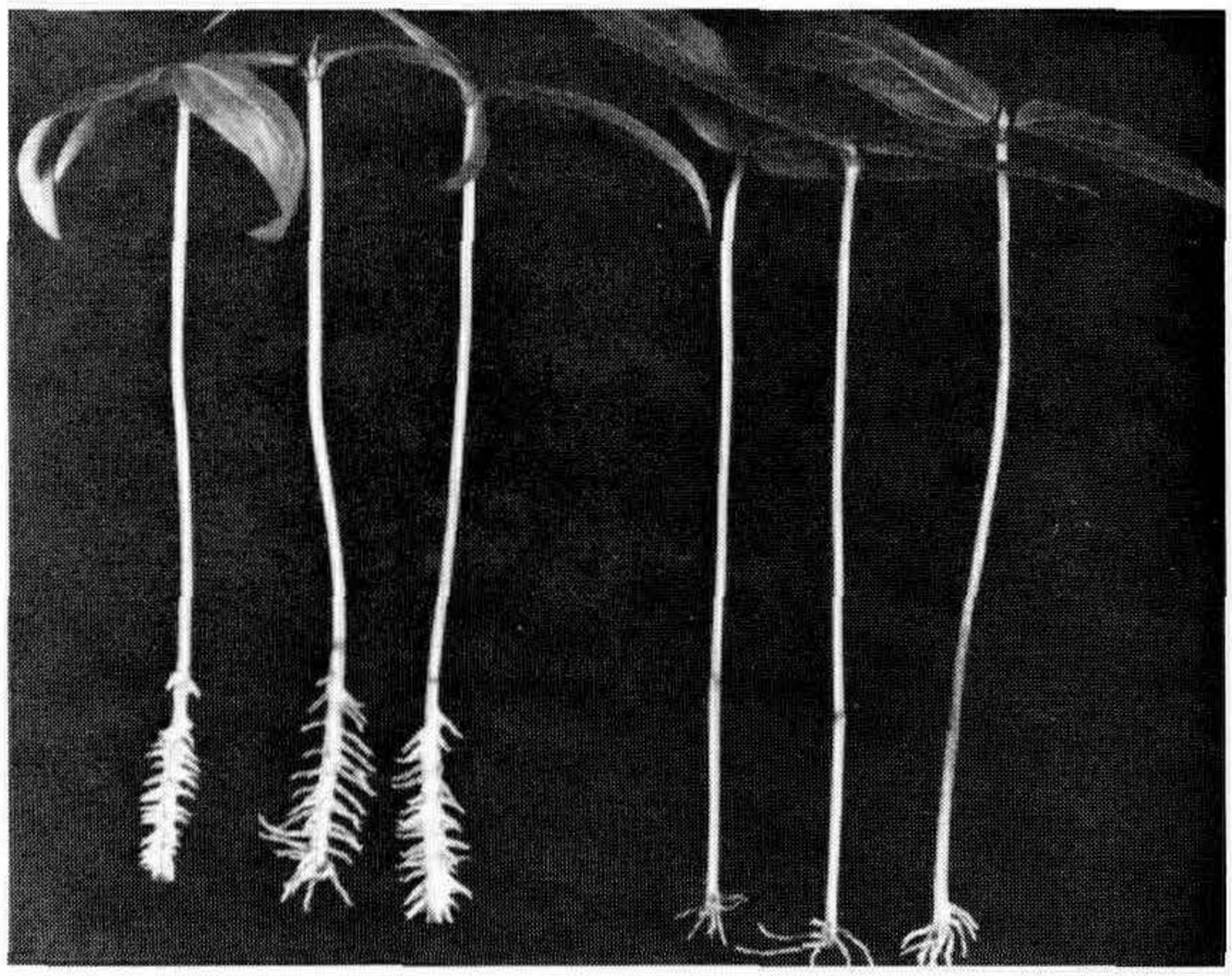

Figure 1. Auxin-induced root initiation and growth of mung bean cuttings. The cuttings on the left were treated with NAA and the cuttings on the right were the water controls. All cuttings were incubated for five days (conditions described in the text)

nucleoli enlarged in these cells approximately 14 h after the cuttings were placed in the rooting solution. Cell division occurred about 10 h later.

The process of root formation involves both cell division and enlargement, and therefore appears to be dependent on synthesis of nucleic acids and proteins. For example, Molnar and La Croix (1972) showed that protein synthesis preceded DNA synthesis and cell division prior to and during rooting in *Hydrangea macrophylla* cuttings. Further, they observed extensive changes in enzymatic activity of the cells responsible for root initiation. Because it is likely that the process of root formation is dependent upon the synthesis of nucleic acids and proteins, chemicals which interfere with or block nucleic acid and/or protein synthesis should inhibit rooting. For example, in mung bean, the exogenous application of 6-methylpurine inhibits root formation presumably due to the production of defective mRNA or due to the inhibition of mRNA synthesis (Blazich and Heuser, 1981).

When mung bean hypocotyls were treated with radioactive uridine,[3H]UR (a precursor of RNA), and thymidine, [3H]TdR (a precursor of DNA), the R-ZP cells showed incorporation of labelled uridine in RNA by 2 h and incorporation of labelled thymidine between 11 and 14 h (Tripepi et al., 1983). This suggests that RNA, protein synthesis, DNA synthesis, and mitosis are important or at least corollary processes of rooting in mung bean cuttings.

Interactions of Auxins with DNA. It is important to understand the mechanism of auxin action for the propagator as well as the basic scientist. The more information known about the action of auxin on root formation, the faster techniques will be developed by growers and propagators to exploit this important phenomenon. Therefore, we are attempting to establish a working hypothesis to explain auxin action relating to root initiation that is based on molecular modeling and subsequent laboratory experimentation.

For a hormone to be active, there must be a receptor(s) even though unequivocal information pertaining to specific receptors in plants is lacking at the present time.

However, in view of existing evidence in the area of molecular biology showing that DNA operates as the template for the transfer of biological information through RNA ultimately resulting in protein synthesis, it is possible that DNA receives the information of many small molecules by interacting with them and, through a modified code, stimulates the production of specific proteins directly involved in the stimulation of a specific response (e.g. root initiation). Certainly, the auxins and other phytohormones are known to affect the physical properties of DNA (Jacobsen, 1977). Witham et al. (1987) have suggested that IAA for example, may intercalate between base pairs and hydrogen bond to DNA. Although the approach of these authors is strictly based on the use of Corey-Pauling-Koltun (CPK) molecular models, it provides insights as to the specific interactions between phytohormones and DNA which may be required for the initiation of varied biological responses, including root formation. Accordingly, they have shown that CPK models of auxins, IAA, α-naphthaleneacetic acid (NAA), and 2,4-dichlorophenoxyacetic acid (2,4-D) may be placed suitably hydrogen bonded in DNA between base pairs. It is interesting to note that although dissimilar chemical and physical features of the three auxins are easily observed when the models are viewed as shown in Figure 2A, the structures are remarkably similar when viewed from above the ring structures (Fig. 2B). These similarities, especially the placement of the hydroxyls, provide for the intercalation or binding between base pairs of DNA

On the basis of such modeling, we speculate that the chemical information inherent in a given auxin structure intercalated into DNA may produce modification of DNA that leads to the initiation of a response such as rooting or, depending upon the hormone, other important plant growth responses. Laboratory experiments are currently under way to determine whether certain auxins actually intercalate into DNA (as shown with models in Fig. 3) and if such a phenomenon is directly correlated with the stimulation of adventitious root production in appropriately treated mung bean plants.

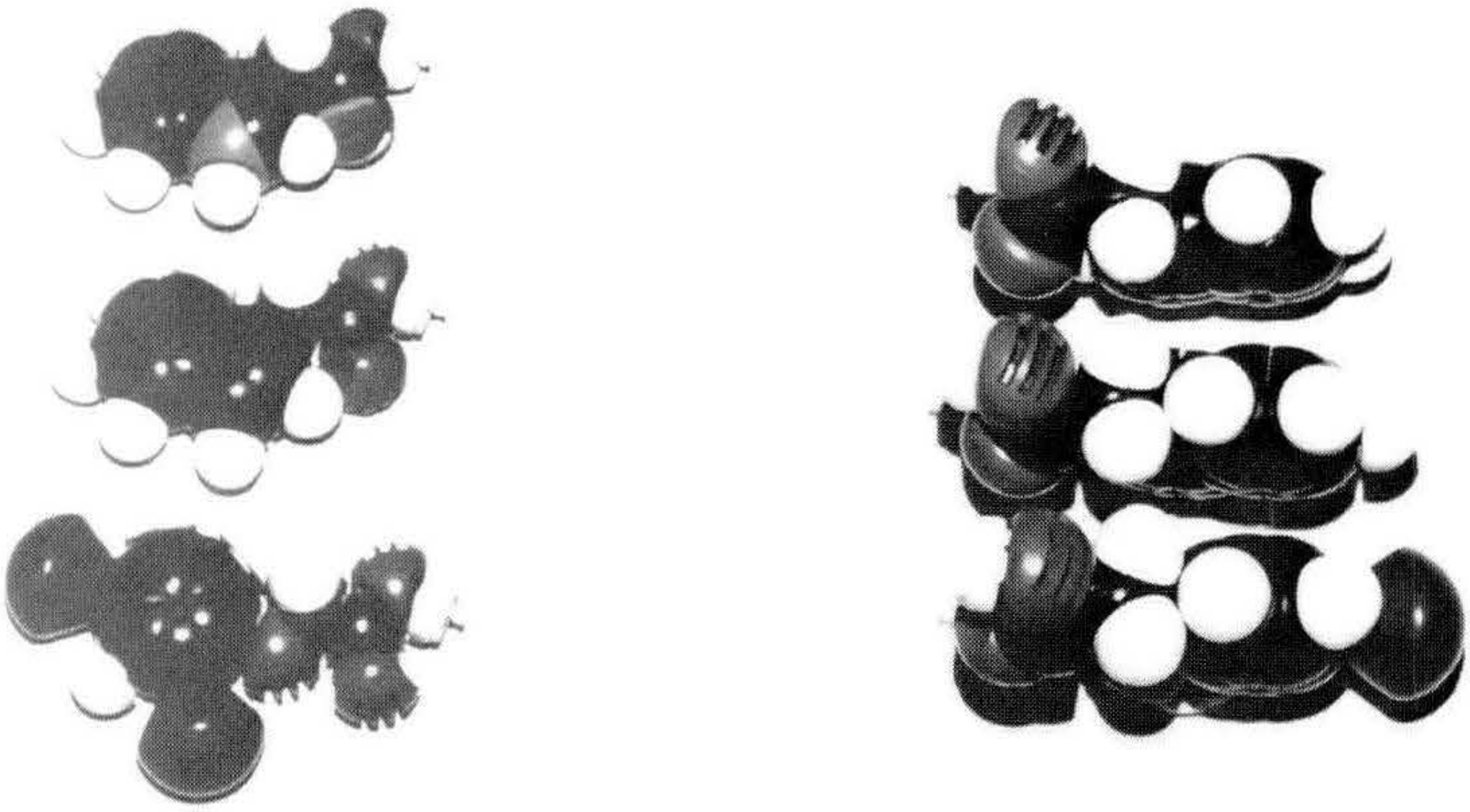

Figure 2. CPK models of representative auxins. (A) Top to bottom: side view of IAA, NAA, and 2,4-D. (B) Top to bottom: IAA, NAA, and 2,4-D CPK models viewed from above the rings.

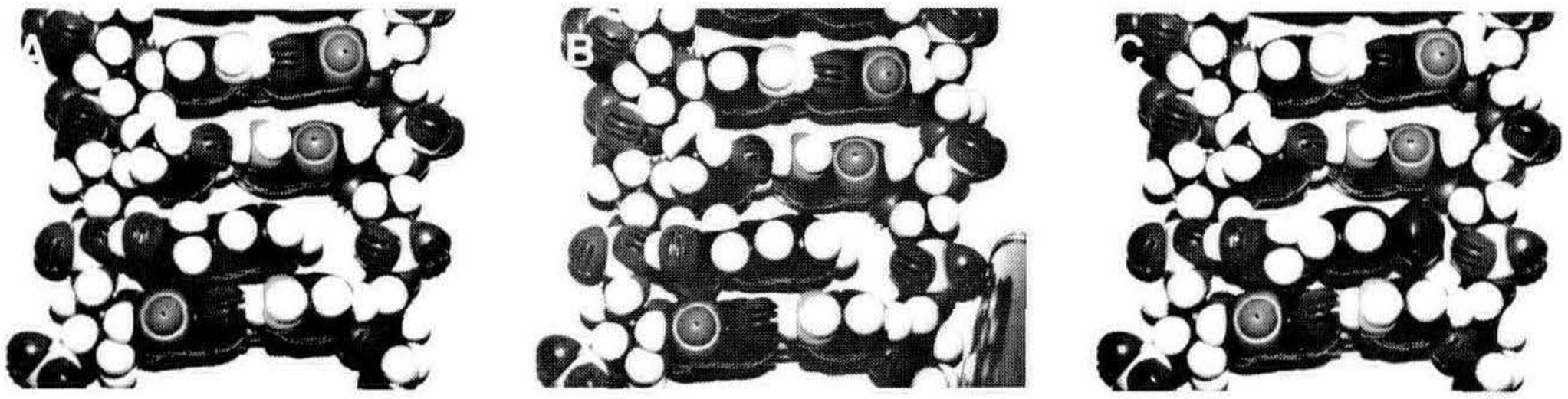

Figure 3. Models of proposed DNA-auxin interactions. (A) IAA interaction with right-handed DNA between thymine-adenine and guanine-cytosine base pairs; (B) NAA interaction with right-handed DNA between thymine-adenine and guanine-cytosine base pairs; and (C) 2,4-D interaction with right-handed DNA between thymine-adenine and guanine-cytosine base pairs.

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Plant Variety Protection

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There are three available forms of plant variety protection in the United States; plant patents, utility patents, and certificates of protection. Each form of protection grants different rights to its owner. This paper describes the procedures for obtaining plant patents, utility patents and PVPA Certificates of Protection in the United States for new plant varieties and the rights obtained by these protection grants. Applications for plant and utility patents are similar but there are different requirements for applications for Certificates of Protection. In all applications for protection, it is important to describe the new variety as completely as possible. Plant patents protect varieties that are asexually reproducible and Certificates of Protection apply to sexually reproducible varieties. Utility patents may be obtained for both asexually and sexually reproducible plant varieties. The cost of obtaining protection is also different. Government fees are lower for plant patents (filing fee $480, issue fee $590, both reducible by 50% for "small entities"), and highest for Certificates of Protection (total fees are about $2600, no reduction for "small entities"). Utility patents are in between (filing fee $710, issue fee $1170, both reducible by 50% for "small entities"), but maintenance fees are required for utility patents before the end of the fourth, eighth, and twelfth years of the utility patent term in order to maintain the patent in effect. No maintenance fees are required for plant patents.

INTRODUCTION

Plant variety protection became available in the United States in 1930 when Congress extended the definition of patentable subject matter to include asexually reproducible plant varieties. There are now three ways of protecting new plant varieties in this country. Two forms of protection are under the U.S. Patent Law administered by the U.S. Patent and Trademark Office ("PTO") and a third form of protection is available under the Plant Variety Protection Act ("PVPA") administered by the Plant Variety Protection Office in the Department of Agriculture.

Plant patents are granted only for plant varieties which have been "asexually reproduced", e.g. by grafting, rooting of cuttings, micropropagation, etc.

A Certificate of Protection is granted by the PVPA for new sexually reproducible plant varieties. A Certificate of Protection applies to the propagating material and not to the finished product, i.e. the plant.

The third form of protection is a utility patent under 35 U.S.C. 101 of the general patent law. Utility patents may be granted for plants that are reproducible sexually and/or asexually.

PROTECTION OF PLANTS UNDER THE PLANT PATENT LAW (35 U.S.C. 161)

Plant patents are obtained by filing an application with the PTO. The required parts of a plant patent application are: (1) a specification; (2) "drawings"; (3) an oath

or declaration; (4) a single claim; and (5) the filing fee. The new variety, must be identified in the application by its "varietal denomination." Usually, this denomination appears in the title of the application.

The specification of the application comprises the description of the new variety and should be as full and complete as is possible. The characteristics of the new variety which distinguish it from its antecedents and from the closest other known variety should also be described and the specification should indicate how and where the new variety has been asexually reproduced. In the case of mutations or "sports," the specification should describe and specify the location and environment of the cultivated area where the mutation was discovered and distinguishing characteristics of the new variety should be described and compared with the parent(s). In general, the characteristics of the plant and its flowers and/or fruit should be disclosed in as much detail as possible, with particular attention to their distinguishing characteristics.

The "drawings" which accompany the specification as part of the application for a plant patent are intended to illustrate the new variety in detail and, in particular, its distinguishing features and qualities. Most commonly, the "drawing" is a color photo illustration which shows as much detail of the new variety as possible, but the specific content of the illustration depends upon the type of plant to be protected. If, for example, the new variety is a flowering ornamental, then the illustration should describe the characteristics and color of the flower in different stages of development. A suitable recognized horticultural color chart, such as the Royal Horticultural Society Colour Chart, should be used to describe the color values.

The plant patent application must conclude with a single claim which specifically forms the basis of protection conferred by the plant patent. The plant patent claim is usually in an abbreviated format that refers to the new variety "substantially as shown and described" in the application.

The plant patent application must be accompanied by an oath or declaration in the form prescribed by the law and the PTO rules. It is very important that the proper "inventor" (breeder) be identified in the oath or declaration otherwise the validity of the patent may be affected.

The application for a plant patent must be accompanied by the appropriate filing fee when filing the application. Currently the regular filing fee is $480 but "small entities" may take advantage of a provision which permits them to pay 50% of the regular government fees. The applicant for a patent is considered a small entity if the applicant or the assignee (the owner) of the application has fewer than 500 employees.

After the patent examiner to whom the application is assigned determines that it is allowable, the applicant is notified that the patent will issue upon payment of the issue fee, currently $590 but also subject to a 50% reduction for small entities. The 17-year period of protection granted by the patent begins at the date the patent issues (not the date of application filing as is the case in some other countries). Unlike utility patents, no maintenance fees are required to maintain the plant patent in full force and effect; therefore, once the plant patent is granted it is not necessary to pay any additional fees during the 17-year term of the patent.

The owner of a plant patent has the right to exclude others from asexually reproducing the plant or selling or using the plant so reproduced. The patent is

infringed by any one of these three acts. Since those selling or using plants which have been unlawfully asexually reproduced are also liable for plant patent infringement, infringement damages may be significantly greater for those improperly using infringing plants to produce commercial products or crops. Sexual reproduction of the patented variety would not constitute infringement of the plant patent since the plant patent rights are limited to the exclusion of others from asexual reproduction of the plant and not from sexual reproduction.

PROTECTION OF PLANTS UNDER THE GENERAL PATENT LAW (35 U.S.C. 101)

All the requirements for patentability under the general patent law also extend to applications for utility patents directed to new varieties of plants. Thus, the requirements of novelty and utility applicable to new varieties under the Plant Patent Act, are the same for utility patents. Both of these requirements can be met by virtually any new variety of plant which is the product of a breeding program or which is a mutation of a preexisting hybrid variety.

An application for a utility patent to a new variety of plant under the general patent law must include the same full and complete description of the new variety as is required under the plant patent statutes and as has been described previously. A major difference however, is that a utility patent may include more than one claim and, thus, the scope of protection available to the patent owner may be increased. For example, a utility patent may include separate claims to the fruit and flowers produced by the plant. This increased protection can be extremely important from a commercial standpoint.

One problem peculiar to applications for utility patents for new varieties of plants is that the disclosure in a utility patent application must be sufficient to enable the public to practice the patented invention upon expiration of the patent. The requirement raises certain problems that make patenting asexually reproducible varieties more difficult than sexually reproducible varieties which can satisfy this requirement by making a deposit of seed. Nonetheless, in important commercial situations, it may be desirable to make the effort to secure a utility patent so as to take advantage of the potentially wider scope of protection. As the law is written, it is possible for the breeder of a new plant variety to make application for both a plant patent and a utility patent or for both a Certificate of Protection under the PVPA and a utility patent.

PROTECTION OF NEW VARIETIES UNDER THE PLANT VARIETY PROTECTION ACT (PVPA)

The PVPA extends protection to new plant varieties reproduced sexually, i.e., by seed, and is similar in some respects to the patent law but there are notable exceptions and differences. The PVPA is administered by the U.S. Department of Agriculture through the Plant Variety Protection Office in Beltsville, Maryland, which grants "Certificates of Protection" following receipt and examination of complete applications. The PVPA applies to almost all sexually reproducible plants.

A requirement for protection under the PVPA is that the new variety must be novel and this requirement is satisfied if there is "distinctiveness, uniformity, and stability" as defined by 7 U.S.C. 2401(a). However, like patents, a variety which has

been a "public variety" as defined by the law, i.e., sold or in public use for more than one year, cannot be protected. The new variety must also have been sexually reproduced and the application must also contain a complete description of the new variety in the form prescribed by the statute for that particular variety. The procedure used in breeding the new variety and its genealogy should also be included in the application. Total U.S. government fees are much higher than for patents, currently about $2,600, and there is no reduction for "small entities."

In addition to the foregoing, the PVPA requires that the applicant submit a seed deposit with the application to the Plant Variety Protection Office.

Infringement of a Certificate of Protection is described rather explicitly in 7 U.S.C. 2541. Among the described acts of infringement are the selling, offering for sale, transfer, importation or exportation of the protected variety. However, using the variety for purposes other than propagation is not an infringement of the Certificate of Protection. For example, grinding seeds to produce flour would not infringe the certificate. One important exception to infringement in the PVPA is the so-called "farmers exemption" which is the right to save seed produced from plants of lawfully obtained protected seed for the purpose of growing crops or for limited sale to other farmers for the same purpose.

Unlike patents, applications for a Certificate of Protection may be filed in the name of the owner of the variety, e.g., the company owning the variety, and need not be filed in the name of the breeder of the new variety. The scope of the Certificate of Protection is limited to the propagating material, i.e., seeds, of the new variety. Thus, the only way to expressly protect the individual plant parts such as the flowers or fruit of sexually reproducible varieties is through utility patents. The term of the Certificate of Protection is 18 years from the date the certificate issues, which contrasts with the 17-year term of U.S. patents.

Copies of the sections of law referred to in this paper and other additional information on the subject of plant variety protection may be obtained from the author upon request.

Propagating Some Native California Perennials

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Over the past 20 years or so, I have had the pleasure of working with several hundred of California's native perennials. A number of them have recently entered the horticultural mainstream, and their nursery propagation and culture have become matters of considerable interest. I would like to share a little of my own practical experience with these plants.

GENERAL CHALLENGES AND OPPORTUNITIES

Growers of blooming perennials face an increasingly "cosmetic" market. Plants are demanded in bloom, well-filled, and looking nearly as if they had just left a florist's greenhouse; natives are no longer exempted. This poses some serious challenges of timing and technique for the propagator, trying to mesh production with sales. Native perennials also come from a variety of habitats, including sites as diverse as open desert and stream-side under coastal redwoods. And different species follow different strategies in dealing with the same conditions, all of which affect their propagation.

Nevertheless, many of the natives in cultivation share a Mediterranean climate, characterized by moist, cool winters and warm, dry summers. Many are active in winter or require a cool period for germination of seeds. This presents its own challenges but also opportunities for relatively inexpensive, "low tech" propagating techniques. Often we can dispense with mist lines, heating cables, and other paraphernalia taken for granted as necessary to the propagation of exotic perennials or woody plants. Here are a few brief notes on my adaptation of common propagating techniques where native perennials are concerned.

PROPAGATION METHODS

Seeding. This is not generally my favored method, though it is certainly the most economical. Many of the plants I'm working with are specific clones, whether nursery-selected or from the wild, with distinctive features like profuseness of growth, abundance and color of flowers, not shared by most individuals. However, in some cases it has been possible to develop, within a few generations, seed strains which are quite consistent in these respects. In any case, many of our native perennials set abundant seeds which are easily collected, dried, and stored (my seed room is an office floor littered with paper bags full of cut stems). In most cases, I simply sow outdoors, in a shaded seed house in fall, letting the natural cool period of early winter stimulate germination. Flats of many species can then be moved indoors to accelerate growth and speed them through the production stages. However some species, including many of our native bulbs and a few non-bulbous perennials like *Lewisia,* germinate more completely and uniformly given a period of stratification. Mixing them in a perlite-based cutting mix in large Ziploc bags, moistening the medium and laying the bags away in an ordinary refrigerator for a couple of months has given consistently excellent results.

Division. Many California native perennials are rhizomatous or have branched rootstocks, making simple division an easy and economical means of clonal propagation. Often I'm dividing from larger plants in one-gallon containers back into the same size containers, though for maximum increase of numbers from limited stock, smaller pieces are planted in smaller, transitional pots. The main challenges have to do with timing. Some species are nearly inactive during warm weather and reconstruct damaged roots and stems poorly if divided during the warmer months; and some others dehydrate easily after being torn or cut apart and will need special protection until reestablished. In either case, fall or winter division minimizes these problems, assuming it allows enough time for plants to achieve full size for spring or summer bloom (this is not always the case).

Cuttings. This has been my preferred method for selected clones of most leafy perennials, being economical of plant material and giving rapid increase of numbers. However, it is not without its problems. Many dryland perennials are highly susceptible to fungus rots under warm, moist conditions—normal propagating house conditions. At the same time, many of the leafier species dehydrate easily as cuttings. The solution is remarkably simple and inexpensive. We maintain a shaded bench, with natural evaporative cooling from a moist gravel floor and no overhead mist, within the larger propagating house; this is shared by flats of many native perennials and a variety of mostly furry-leaved shrubs with the same susceptibilities to disease. Most species perform well with only mild (e.g. Hormex #3) or no rooting hormones.

SOME POPULAR NATIVE CALIFORNIA PERENNIALS

Here is a thumbnail sketch of our experience with some of the more popular California perennials.

Asarum caudatum (wild ginger). We use all three basic methods with this species but continue to lag far behind demand in the marketplace. Fall-sown seeds are an easy, economical method—if the seeds can be collected in the first place. We lose many to our native voles (field mice), just as the pods are ripening. Division is easy but not terribly productive, unless the plants can be left alone for a couple of years in large beds; first-year plants make few rooted shoots. Small, even single-node cuttings of the creeping stems are successful but are slow to initiate new growth.

Dudleya spp. These native succulents are easy to handle. Plants not subjected to overhead sprinkling set abundant seed, which germinates readily under moderate to warm conditions. Those species which produce multiple trunks are easily divided, and unrooted shoots, after drying off the wounded bases for a day or two, may be planted in ordinary cutting medium, without mist and with or without bottom heat.

Eriogonum spp. (wild buckwheat). Many of these are actually low shrubs, but we tend to lump them with blooming perennials. Most, even of the high mountain species, are easily raised from seeds, though damping off can be a problem under greenhouse conditions. Cuttings of just-matured shoots with firm bases are successful for many species; this tends to be in summer and early fall, in our climate. Several species produce groups of shoots radiating from a common node, which can be split with well-sharpened shears.

Festuca spp. (fescue). Our native festucas are mostly dense-growing bunchgrasses with many shoots per clump. This makes them ideal subjects for division.

Normally we divide them into fairly small, rooted pieces, planted in 2½-in. pots for later shifting, and keep them well shaded immediately after division. Unrooted shoots may be treated as cuttings, if the basal nodes are intact. We place them on a shaded bench without mist.

Heuchera spp. (alum root; coral bells). There are now a good variety of native species and half-native hybrids of this group in nurseries. Seed propagation is easy, but current named clones are far superior to the general run of seedlings. All can be divided successfully most of the year, though some of the large-leaved, heavy-stemmed hybrids will yield better numbers from cuttings taken in repeated rounds, every few months.

Iris, Pacifica group. These include some of our most spectacular perennials. Seeds germinate readily after a month or two of cool, moist weather; they also provide an interesting assortment of new material, though mostly inferior to named parent clones. The plants are nearly dormant during warm weather, so fall and winter division tend to be most successful; even so, many older leaves will die back after division, and the plants will look fairly shabby for a while.

Lewisia cotyledon hybrids. These are showy native succulents, derived from native material in our cool northern mountains; none of them do well in California's Central Valley heat. I select the best of each year's crop for seed stock and stratify the seeds (usually they begin to sprout in the bags after a couple of months). Some of the more prolific clones may be done by division or cuttings (shade/no mist); however, many individuals refuse to produce more than one rosette for several years.

Mimulus (Diplacus), shrubby species and hybrids (bush monkey flower). These are cheery but somewhat temperamental natives. They are easy to propagate from seeds, sown almost any time; however, they damp off easily and are highly subject to botrytis. The latter is also true for cuttings, which are otherwise easy to root. We use a variety of locations, all without mist.

Monardella spp. (coyote mint). These are small, semi-shrubby perennials which look and behave much like the true sages (*Salvia*). They are not difficult from fall-sown seed, but the seedlings are so variable, and the plants so profuse and easily propagated by cuttings, that cuttage is clearly preferable for my purposes. The shady cutting bench, with no mist, gives quick results and avoids various fungus afflictions.

Penstemon (beard-tongue). This is an extremely diverse group, which could easily be the subject of its own article. Most are easy to propagate from fall- and winter-sown seeds. Some of the mountain species seeds require an extended cool period to germinate, while others are not so particular. The matting species root as they travel and can be divided economically into rooted chunks for replanting. All of our native species may be propagated by cuttings, so long as they are taken from the lower, clearly vegetative portions of stems and not along the flowering portions (cuttings taken just below the flower clusters look vegetative and generally root, but often fail to produce new shoots).

Salvia sonomensis (Sonoma sage). This is one of the most beautiful, but unfortunately also one of the touchiest, of our native ground covers. I have not tried seeding, though germination should not be difficult. Large plants can be divided into rooted pieces for replanting, though cuttings give a better rate of multiplication. In either case, losses can be expected from a variety of lethal diseases —

whether in the greenhouse or in the field. We do our cuttings on the shade bench and water them just enough to avoid wilting. Plants in the field are hand-watered. Shading would probably help in further reducing our losses.

Sisyrinchium bellum (blue-eyed grass). Several clonal selections of this small iris relative are now available. Seeds are easy to grow, sown in fall, but are generally inferior to this selected stock. The plants make dense clumps and are easily divided into groups of rooted shoots for replanting. Since they are primarily cool-season growers, this is best accomplished in fall and winter.

Vancouveria spp. (inside-out flower). These are carpeting, shade-loving perennials with fernlike leaves. I have no experience to offer with seeds, though I suspect they are not difficult. The plants are easily divided in fall and winter, and unrooted portions of the slender rhizomes can be planted as cuttings in pots or flats, with no rooting hormone. Although they are active most of the year, we have suffered heavy losses to post-division "shock" (sudden wilting and decline) with summer divisions, regardless of shading.

Zauschneria spp. (California fuchsia). The zauschnerias have a variety of growth habits affecting their propagation. All are easy to propagate from seeds, sown at almost any time under moderate to warm conditions, though the resulting seedlings are extremely variable. Some individuals make intricate networks of rhizomes and are easily divided, at least during the cooler months (postdivision wilting is a problem in summer heat). Cuttings root rapidly most of the year, but are not necessarily "easy" to root. We are most successful with near-tip cuttings in spring and early summer, placed on the shade bench or in a shaded, closed house to avoid wilting. Hot weather anytime soon after the cuttings are stuck often results in heavy losses, which appear to result more from physiological problems than from disease.

New and Interesting Native Cultivars and Their Propagation

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With all of the interest in native plants in recent years, there has been a definite resurgence of activity in the selection of new forms and rediscovery of nearly forgotten gems. This paper will briefly describe some of the best of these plants and their propagation.

***Aesculus californica* 'Canyon Pink'**. To date this is the only named selection of our native buckeye. This selection has the normal attributes of the species: silver-grey bark, bright apple-green new growth that turns a pleasing mid-green as it matures, and the large brown round seeds in the fall. The distinctive feature of this cultivar is the large conch-shell pink inflorescence, and a free-flowering disposition. This tree may be grown as either a standard or a multi-trunked specimen. Established trees are drought tolerant in all but the hottest climates, but will go dormant when they are drought stressed. Specimens that are watered regularly will go deciduous in the early fall months. This outstanding selection was made by the late Dara Emery of the Santa Barbara Botanic Garden from seed collected in Monterey County. 'Canyon Pink' is difficult to propagate, and currently the only method that has had any success is grafting.

***Arctostaphylos* 'Bert Johnson'**. One of the most adaptable of the manzanita ground covers, 'Bert Johnson' rivals *A. uva-ursi* 'Point Reyes' in its tolerance of heat and drought. Plants have withstood temperatures of 113°F in full sun at Rancho Santa Ana Botanic Garden with no ill effects noticed. This cultivar also performs well in shaded coastal gardens. Plants are extremely dense growers and do not require any pinching or pruning. Specimens in containers or those planted at the top of a low retaining wall will gracefully cascade. Leaves are lightly hairy, and vary from mid-green to grey-green with the season. Small clusters of pale pink, urn-shaped flowers appear in early spring. This selection has been around for quite a number of years, but was finally named earlier this year for Bert Johnson, one of the East Bay Regional Parks Botanic Garden's gardeners. 'Bert Johnson' was selected by James Roof of the East Bay Regional Parks Botanic Garden, and is actually the type plant from which *A. edmundsii* var. *parvifolia* was originally described. [Botanical Editor's note: This taxon is now understood to be a hybrid between *A. glandulosa* and *A. nevadensis*] Plants are easily grown from cuttings taken from November to February and treated with 0.8% IBA and given bottom heat from 65 to 70°F. Cuttings may take from 1 to 3 months to strike roots.

***Artemisia pycnocephala* 'David's Choice'**. This plant is a dense, low-growing evergreen perennial which is vigorous and good looking throughout the year. The soft grey, finely divided foliage and dense growth habit are the best features of this David Amme, 1980 selection from the Point Reyes peninsula. This cultivar is longer-lived and better behaved in both nursery containers and garden situations

than is the straight species. 'David's Choice' is moderately drought tolerant, but usually looks best when grown with adequate water. Overhead watering may rot the dense foliage in hot climates. Flower stalks may be removed as they form to better maintain the clean rounded growth habit. This plant was introduced by California Flora Nursery in Fulton, California in 1983 and won an Award of Merit from the California Horticultural Society in 1988. It is easily grown from vegetative tip cuttings at any time of the year.

***Calystegia macrostegia* 'Anacapa'**. This plant is an extremely vigorous lush-looking evergreen vine, which may cover a small house in about two to three years. The pink, three-inch, morning glory flowers are freely produced through the warm months of the year. The triangular leaves are bright green. This vine climbs by twining, and rapidly builds up a layer of thatch which can be removed by hard pruning. David Verity of the Mildred Mathias Botanic Garden at UCLA made this selection from a plant growing on Anacapa Island. It is easily grown from vegetative tip cuttings whenever the plant is in active growth.

***Ceanothus griseus* 'Diamond Heights'**. A very unusual variegated form of the Carmel creeper, formerly called *C. griseus* var. *horizontalis*. The oval-shaped leaves are a pale chartreuse color with a central splotch of the normal dark green. This plant is slower growing than all other selections of *C. griseus*. Flowers are a pale grey-blue and are hardly noticed because of the loudness of the foliage. The foliage will burn in direct hot sun, so it is best used in partial shade or eastern exposures. Plants stay low and need less pinching than other selections in this group. 'Diamond Heights', along with the other selections of *C. griseus*, is not drought tolerant except when planted in coastal situations. When planted in other areas, these plants will require fairly regular watering. This plant was discovered in a landscape planting in the Diamond Heights area of San Francisco. It is a little less successful in propagation than other selections of *C. griseus*, but can be readily grown from tips, seconds, and thirds under fairly standard conditions. As with all the *Ceanothus*, the cutting material should be semi-hard (too soft and the material will rot, too hard and the percentage that will root is low and will take a long time).

***Chrysopsis villosa* 'San Bruno Mountain'**. Nearly ever-blooming, this superior plant has a dense growth habit and is widely adapted to garden culture. Plants will reach 4 to 6 in. high with a spread of about 2 ft. This sterile selection will flower continuously during the warm months of the year, which explains its most important need—it must be regularly dead-headed. Experiments at Cal-Poly, San Luis Obispo have shown that this may be done with a weed-whip without damaging the plants. 'San Bruno Mountain' was selected by Ted Kipping from San Bruno Mountain just south of San Francisco. Plants are readily grown from tip cuttings taken in the spring before the first wave of flowers, and secondarily through the summer months.

***Dudleya* 'Frank Reinelt'**. This *Dudleya* is good looking throughout the year. The grey, terete leaves form 3- to 6-inch rosettes, and a mature plant may reach 3 ft across and a height of 18 in. The branched salmon-colored flower stems carry numerous pale yellow urn-shaped flowers. This plant is the result of controlled crosses made by Frank Reinelt, and was only recently named by Wayne Roderick. Plants sold as *Dudleya* 'Anacapa' are synonymous with 'Frank Reinelt'. It is easily

grown from cuttings (individual rosettes) which are placed in a shaded area to callous for a couple of days and then placed in a flat or pot of well-drained material.

***Erigeron glaucus* 'Cape Sebastian'**. This is the most dwarf selection of *Erigeron glaucus* to date. Plants grown in full to mostly sunny conditions will grow from 2 to 3 in. tall with a spread of 18 to 24 in. Plants tolerate heavy clay soils, and moderate amounts of water. The lavender-pink flowers appear on short stems and are roughly the size of a nickel. The plants will flower intermittently through the year with a profusion of blooms in April and May. As with all forms of *Erigeron*, this selection will require dead-heading. This plant was selected by Brett Hall of the U.C. Santa Cruz Arboretum from Cape Sebastian in southern Oregon. Plants are readily grown from cuttings. Nursery grown plants may temporarily lose their dwarf growth habit if they are grown in too much shade or with too much fertilizer, but will behave once they are planted out.

***Erigeron* 'W. R.'**. An extremely durable clone, originally collected by Wayne Roderick in Del Norte County. This plant survives extremes of heat (over 115°F) and cold (to at least -6°F). Plants apparently grow equally well in full sun (even with extreme heat) or partial shade. This selection has long flower stems and a very compact mat of basal strap-like leaves. The lavender daisy flowers are from 1 to 1½ in. across and have pale yellow centers. 'W. R.' is easily propagated from vegetative tip cuttings taken at any time of the year.

***Eriogonum fasciculatum* 'Theodore Payne'**. An excellent ground cover form of California buckwheat, this form has been in and out of the trade since its discovery at Point Mugu in 1952 by Mr. Dana Bowers. This plant has needle-like, grass-green leaves and small off-white balls of tiny flowers. 'Theodore Payne' is easily grown in full sun and well-drained soils. It is drought tolerant when established. This cultivar is easily propagated from partially firm (not soft) new growth in mid to late spring.

***Eriogonum fasciculatum* 'Warriner Lytle'**. It is most unfortunate that this beautiful plant is such an ugly duckling when it is grown in containers. Leaves are narrow and olive green. The foliage mat of this ground cover selection will spread to 3 ft or more across and will reach from 6 to 8 in. high. Dense clouds of tiny off-white flowers crown the plants for 2 months in the late summer and early fall. This plant is especially delightful when it is grown at the front of a dry border, or lightly cascading about boulders or low walls. 'Warriner Lytle' is a recent introduction from the Theodore Payne Foundation and is named for one of their dedicated friends. Plants are easily propagated from partially firm (not soft) new growth in mid to late spring.

***Eriogonum umbellatum* var. *polyanthum* 'Shasta Sulphur'**. This plant has been in the trade for a number of years, but was finally given a cultivar name earlier this year. 'Shasta Sulphur' has a delightful dome-like growth habit for a number of years, before the center dies out and the plant becomes senescent and needs to be replaced. As with nearly all eriogonums, this plant is brittle—if the plant is broken or damaged when it is young it almost never fully recovers. Aside from these negatives, this is a truly spectacular plant in the garden. The grey-green spatulate leaves are produced in a whorl-like array. Dense umbels of vibrant

canary yellow blossoms appear in May and last for a month. 'Shasta Sulphur' was selected by Warren Roberts, superintendent of the U.C. Davis Arboretum. Cuttings are best taken in spring, and consist of one "whorl" of leaves and the segment of stem below it (do not include any part of the lower "whorl"). Treat the cuttings with liquid 0.4% IBA and place them in a flat with bottom heat between 65 and 70°F.

***Festuca californica* 'Serpentine Blue'**. This is the best selection of California fescue that I am aware of. The stiff leaves are fairly broad for this species and are a beautiful shade of steel-blue. The inflorescences are particularly rigid in this selection, and will normally last well into the winter in a garden situation—unlike any other selection of this species. Plants do best in partial shade, and benefit from additional summer water. 'Serpentine Blue' was selected by Roger Raiche of U. C. Berkeley Botanical Garden from a plant he found in Marin County. This plant is easily grown from division or from "cuttings". A mature clump can be divided into dozens of 1/8 to 1/4 in. "cuttings" with or without roots, and placed untreated into a cutting flat. These "cuttings" will promptly root.

***Festuca rubra* 'Jughandle'**. This is the most dwarf selection of red fescue, with mature plants reaching from 3 to 6 in. high. The thread-like leaves are a steel-blue color, and contrast nicely with the silvery, broad awns of the inflorescence. Plants look best with additional summer water, and are not bothered by heat. Older plants may die back at the center or back of the clump, but this is generally not a severe problem. This plant was found along the Mendocino coast by David Amme. 'Jughandle' is grown by division.

***Fremontodendron californicum* 'Margo'**. This plant is an exciting newcomer from the East Bay Regional Parks Botanic Garden. The plant has bright green, nearly glabrous foliage and produces a myriad of bright yellow flowers in April and May. The plant has a low, spreading to arching growth habit. Plants prefer full sun, well-drained soils, and little to no summer water. Established plants require drought. This plant was discovered by Daniel Campbell in Yuba County. Plants are said to be especially easy to root from cuttings taken in November.

***Heuchera* 'Lillian's Pink'**. This plant is thought to be a hybrid between *H. pilosissima* and *H. sanguineum*. Plants form a somewhat loose rosette of lush, hairy, pale grey-green leaves. The pink flowers are carried on a 2-ft inflorescence. This selection was made by Ron Lutsko, Jr. about 3 years ago. The plant occurred as a chance seedling in Lillian Henningsen's garden. Plants are propagated from cuttings or from division of established clumps.

***Heuchera* 'Opal', 'Susanna', and 'Wendy'**. This trio of heucheras has the same parentage as the better known 'Santa Ana Cardinal' and 'Genevieve': *H. maxima* × *H. sanguineum*. In fact, all of these plants are siblings raised by Dr. Lee Lenz in 1953 at Rancho Santa Ana Botanic Garden. They have been given clonal names over the past 37 years: 'Santa Ana Cardinal' (1958), 'Genevieve' (1974), 'Susanna' (1974), 'Wendy' (late 70s or early 80s), and 'Opal' (1990). The latter three are described here: 'Susanna' is nearly identical to 'Santa Ana Cardinal' with its bright green shiny lush rosette of leaves and 3-ft inflorescences of bright red flowers. The primary difference being that 'Susanna' starts blooming about 2 weeks later. 'Wendy' has much larger grey-green hairy foliage in looser rosettes and 3-ft

inflorescences of rosy pink flowers. This selection is particularly free flowering. 'Opal' has large grey-green rosettes of foliage and 2-ft inflorescences of white flowers which turn pale pink as they age. All of these selections are best grown in masses in light shade. Established plants are moderately drought tolerant. Plants are easily propagated from cuttings, but there are typically few cuttings available per plant. Established plants may have the top portion of their rosette removed (as a cutting) and numerous side shoots will quickly develop into cutting sized portions. All five of these plants are now being grown from tissue culture and should become readily available to the trade in a year or two.

***Iris* 'Canyon Snow'**. This selection is probably the most desirable and easily grown of the Pacific coast hybrid iris. The leaves are bright green and will reach about 1 ft high. Plants slowly form large clumps. The large, flat, white flowers have bright yellow eyes on the falls. As with most of our native iris, these plants do not typically have an active root system in the summer months, so care must be taken not to overwater the plants. 'Canyon Snow' was selected by Dara Emery of the Santa Barbara Botanic Garden. Plants are easily grown from divisions made in late fall, just as the new roots are pushing. If you wait too long, the new roots will be broken and the plants will not establish themselves very quickly.

***Keckiella* 'Dick Straw'**. This plant has been around for many years, yet it has never been formally introduced. It is a segregate from a controlled cross of *K. antirrhinoides* and *K. cordifolia* made by Dr. Lee Lenz at Rancho Santa Ana Botanic Garden, and is named for the botanist who originally segregated the genus *Keckiella* from the genus *Penstemon*. This plant is particularly vigorous and showy. It has an arching growth habit and will reach 3 to 4 ft high and a spread of up to 6 ft. The bicolored flowers are produced by the hundreds and are dark orange on the outside and yellow-orange on the inside. Plants grown in hot interior climates will go completely dormant during the summer months, usually about a month after flowering in late May. New plants may be grown from vegetative new growth taken in the spring, or from dormant wood cuttings taken in the fall. Plants grown from the new growth generally perform better.

***Lavatera* 'Purisima'**. A vigorous, unusual hybrid between our native *L. assurgentiflora* and its Baja California cousin, *L. venetus*. This plant was recently introduced by Tree of Life Nursery. Plants have a low, spreading growth habit reaching 2 to 3 ft tall with a spread of about 8 ft. The luxuriant rich green foliage is unlike most native plants. Plants perform best with regular deep watering. The mallow-like, rose-magenta flowers have deep violet centers. Cuttings are best taken in spring from semi-hardened new growth.

***Malacothamnus* fasciculatus 'Edgewood'**. An outstanding grey foliage shrub. The stems of this plant are densely covered with a velvety fur, the dark grey leaves are less heavily coated. Flower spikes are 2 to 3 ft long and carry many 1- to 2-in. pink hollyhock-like flowers. This plant was selected and introduced by Yerba Buena Nursery in 1991. As with most *Malacothamnus*, this plant is well suited for growing on slopes and for erosion control due to the production of underground runners, but it adapts well to garden culture. New plants are readily produced from vegetative semi-hardened new growth in the spring and early summer, or from

divisions. [Botanical Editor's note: *M. arcuatus*, under which name this cultivar was originally named, is now recognized under *M. fasciculatus*.]

***Philadelphus lewisii* 'Goose Creek'**. This plant is the double-flowered selection of our native mock orange. The plant was collected by Ray Collett of the U.C. Santa Cruz Arboretum and was introduced by Wintergreen Nursery. The plants have a fountain-like growth habit and will reach 6 ft high with a slightly wider spread. This shrub is deciduous. Plants are easily grown in most gardens in either full sun or partial shade. Cuttings may be taken from semi-hardened new growth or from dormant wood, the latter being particularly easy. [Botanical Editor's note: Originally described under the subspecies *californicus*, which is no longer recognized.]

***Rhamnus californica* 'Mound San Bruno'**. An unusually dense, small-leaved selection of our native coffee berry. The name is a pun referring to both the plant's growth habit and its place of origin, San Bruno Mountain. Young plants will quickly grow 2 to 3 ft tall and will have a somewhat open growth habit. But within 2 years, the plants fill in and continue growing at a slow rate to 4 ft in height with a spread of about 6 ft. This plant was discovered and named by Roger Raiche of the U.C. Berkeley Botanical Garden. Plants are relatively easily grown from semi-hard cuttings taken in spring.

***Salvia clevelandii* 'Winnifred Gilman'**. An outstanding plant, selected by Ron Lutsko, Jr., and recently introduced by California Flora Nursery. This plant, and the later listed blue and white form are the only clones of *Salvia clevelandii* at this time, all others ('Allen Chickering', 'Aromas', 'Pozo Blue', 'Whirly Blue', etc.) are all hybrids between *S. clevelandii* and *S. leucophylla*. This small sage will grow 3 to 4 ft tall, and has spikes of dark lavender-blue flowers in late spring and early summer. Plants perform best in full sun and well-drained soils. As with all of the selections of our native shrubby salvias, this plant should be cut back hard on a yearly basis in late fall or early winter—from a third to a half of the growth should be removed. Plants are easily grown from semi-hard cuttings taken in spring.

***Salvia spathacea* 'Kawatre'**.The hummingbird sage, one of my favorite plants, should be much more widely grown. The plants are fairly good looking in containers, and few people can resist an impulse buy of this plant when it is in bloom. The broad light green leaves are primarily basal and have a delightful fruity fragrance, but it is the showy 2 to 3 ft flower spikes which command attention. The plants spread slowly underground to form slightly mounded colonies. Plants perform best when grown with additional summer water and in partial shade conditions. This selection was made by Nevin Smith from material collected in the Santa Cruz Mountains. Plants may be grown from divisions or from cuttings.

In closing, I would like to mention two new promising selections which are currently undergoing testing. These plants have not been formally named yet, but may be in the near future.

***Rhamnus californica* "Ed Holm's Seedling"**. An exciting development arising from the Saratoga Horticultural Foundation's introduction program. The plants have broad, lush foliage which is bright green when new and becoming dark green as they mature. Plants produce a quantity of ½-in. red berries in the fall. This plant was grown from seed collected along Skyline Boulevard in San Mateo County by

Ed Holm. It is currently not available, as it is undergoing testing throughout California at this time.

***Salvia clevelandii* "Blue and White"** This very distinctive clone appeared in a flat of wild collected seed from San Diego County grown at Rancho Santa Ana Botanic Garden. Mature plants of this unnamed selection will grow from 3 to 4 ft tall with an equal spread. The small leaves are grey green. The most unusual feature of this selection is that the flowers are either white or blue- violet. The color varies within each whorl of flowers such that the appearance of the plant changes almost daily. This plant will be distributed to a few gardens throughout the state to test its adaptability before being formally released to the nursery industry. Look for this new plant from Rancho Santa Ana Botanic Garden within the next 2 years. [Author's note: Since the presentation of this paper, this plant has been given the cultivar name of 'Betsy Clebsch'.]

Treeshelter Use in Producing Container-Grown and Landscape-Grown Trees

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INTRODUCTION

Treeshelters are now used in the establishment of trees in the landscape (Evans and Potter, 1985; Frearson and Weiss, 1987; Potter, 1988). These treeshelters are cylindrical or square, translucent, polypropylene tubes of varying height (usually 60 to 150 cm) which are placed around seedlings or transplants at planting time. Trials in England have shown that placing these shelters over transplanted or naturally sprouted seedlings of various species improved the seedling survival rate. Treeshelters protected seedlings from herbicidal drift and animal browsing, but their most attractive characteristic was the 60% to 600% increase in plant height (Frearson and Weiss, 1987; Potter, 1988, 1991). Growth rate increases have been attributed to the enhanced growing environment around the plant achieved with the use of the treeshelter. Increases in ambient temperature, relative humidity, and CO_2 concentration have all been suggested as probable causes for increased growth (Frearson and Weiss, 1987; Potter, 1988). The nature of the relationship among these environmental parameters and their potential effect on treeshelter-grown plants is not clear.

Treeshelters are intended for and customarily used in the landscape (Potter, 1991). The use of treeshelters during the production of container-grown plants has not been explored. However, based on work conducted with treeshelters in the landscape, plant growth could be enhanced and plants more suitable for transplantation to the landscape could be produced with the use of treeshelters in the nursery. The objectives of our work were to: (1) determine how three container-grown, landscape species would respond to treeshelters in a nursery, (2) determine the water use characteristics of these trees grown with or without a treeshelter, and (3) compare the growth and survival of seedlings replanted into the landscape, grown with or without a treeshelter and receiving 7 to 14 times less water than in the nursery.

MATERIALS AND METHODS

Nursery Experiment. Three tree species were selected for the study: *Cedrus deodara* (deodar cedar), *Quercus ilex* (holly oak), and *Magnolia grandiflora* (southern magnolia). In February, 1990, 30 young plants of each of the three species grown in 1-gal containers were transplanted into 5-gal containers. A treeshelter (Tubex, St. Paul, Minnesota) was placed over 10 plants of each species. The bottom of the shelter was pushed into the container medium approximately 3 cm. A stake was driven down along side the shelter and the shelter tied to it for support.

Height and trunk caliper (at the top of the pot) were measured for each experimental plant at the beginning of the experiment and on December 12, 1990.

None of the trees were pruned during the experiment. After the first year, some trees had the treeshelter removed from around them and they were allowed to grow another year without a shelter, some plants remained in the shelter, and the control plants were unsheltered.

Water use measurements were taken twice during the growing season (5/1/90 and 6/7/90). Plants were watered heavily and allowed to drain to container

Table 1. Response of *Cedrus deodara*, *Quercus ilex*, and *Magnolia grandiflora* trees to treeshelters. Hgt=Height, Cal=Caliper, SFW=Shoot Fresh Weight, SDW=Shoot Dry Weight, RFW=Root Fresh Weight, and RDW=Root Dry Weight.

Treatment	Hgt (cm)	Cal (mm)	SFW (g)	SDW (g)	RFW (g)	RDW (g)
			Cedrus			
No stake, no shelter - Years 1,2	170 B	34.7	2710	1314	2357	888
No stake, shelter - Year 1	211 A	35.3	2623	1264	227	1862
No stake, shelter - Years 1,2	212 A	29.7	2293	1092	2373	809
	NS	NS	NS	NS	NS	
			Quercus			
No stake, no shelter - Years 1,2	183 C	29.0 A	1600	966	1425	669
No stake, shelter - Year 1	242 B	30.0 A	1906	1175	1295	614
No stake, shelter - Years 1,2	271 A	30.0 A	1763	1040	1266	603
Staked, no shelter	221 BC	18.5 B	-	-	-	-
		NS	NS	NS	NS	
			Magnolia			
No stake, no shelter - Years 1,2	116 B	19.0	1170	536	659	223
No stake, shelter - Year 1	163 A	15.3	640	325	434	148
No stake, shelter - Years 1,2	176 A	19	1043	487	565	203
	NS	NS	NS	NS	NS	

NS - Not Significant.
Values followed by different letters are significantly different at p=0.05 using Scheffe's Mean Separation Procedure.

capacity (1 h). The plant and container were weighed and placed back into the nursery bed. After 24 h the plant and container were re-weighed. The difference in weight was defined as the water used and consisted of water transpired by the plant and water evaporated from the soil surface.

RESULTS AND DISCUSSION

Height increases of trees grown in shelters for one year were 24%, 32%, and 41% greater than unsheltered trees for *Cedrus*, *Quercus*, and *Magnolia*, respectively (Table 1). Only *Quercus* trees growing in shelters had a significant height increase over unsheltered trees during the second year. Treeshelters did not significantly affect the caliper of any one of the three tree species. Staking of *Quercus* trees significantly reduced trunk caliper (Table 1, *Quercus* trees staked with no shelter). *Quercus* trees grown in shelters for one year developed into high-quality trees ready to be transplanted into the landscape. Once the shelter was removed from around *Cedrus* trees, they were incapable of supporting their own weight. Leaves of *Magnolia* trees grown in shelters deteriorated and senesced leaving the main stem with very few leaves.

While it has been shown that the root growth of these tree species is reduced while growing in a shelter during the first year of growth (Burger et al., 1992), the difference disappears during the second year. There were no significant differences in shoot or root fresh or dry weights of trees growing with or without shelters after two years (Table 1). Only *Cedrus* trees grown in shelters and measured on 6/7/90 used significantly less water than those grown without shelters (353 versus 577 ml/24 h). There were no significant differences in water use of *Magnolia* and *Quercus* trees grown with or without shelters on either test date with values ranging from 253 to 337 ml/24 h for *Magnolia* and 340 to 367 ml/24 h for *Quercus*.

MATERIALS AND METHODS

Landscape Experiment

Fifteen seedlings of coast redwood (*Sequoia sempervirens*), seeded on May 5, 1989, were selected at random on May 10, 1990 from seedling flats. They were immediately planted in Falkirk Park (San Rafael, California) in three north-south rows (150 cm between plants). Height and caliper measurements were taken of each tree before treeshelter treatments were imposed. Ten treeshelters were placed over randomly selected seedlings. Beginning 14 days after planting, the seedlings were irrigated as follows: (1) five seedlings in shelters received 1 liter of water every 7 days (SR schedule), (2) another five seedlings in shelters received 1 liter of water every 14 days (S schedule), and (3) the remaining five control, unsheltered trees received 1 liter of water every 7 days. These irrigation schedules were maintained until October 29, 1990, when the first rain occurred.

RESULTS AND DISCUSSION

Redwood seedlings growing in treeshelters and irrigated with 1 liter of water every 14 days (S schedule) were taller than unsheltered trees receiving 1 liter of water every 7 days (Fig. 1). Sheltered trees irrigated with 1 liter of water every 7 days (SR schedule) were 26% to 28% shorter than those in treeshelters with the S schedule. Trees irrigated under the SR schedule were 60% to 63% taller than the unsheltered trees irrigated similarly; however, this height increase was not statis-

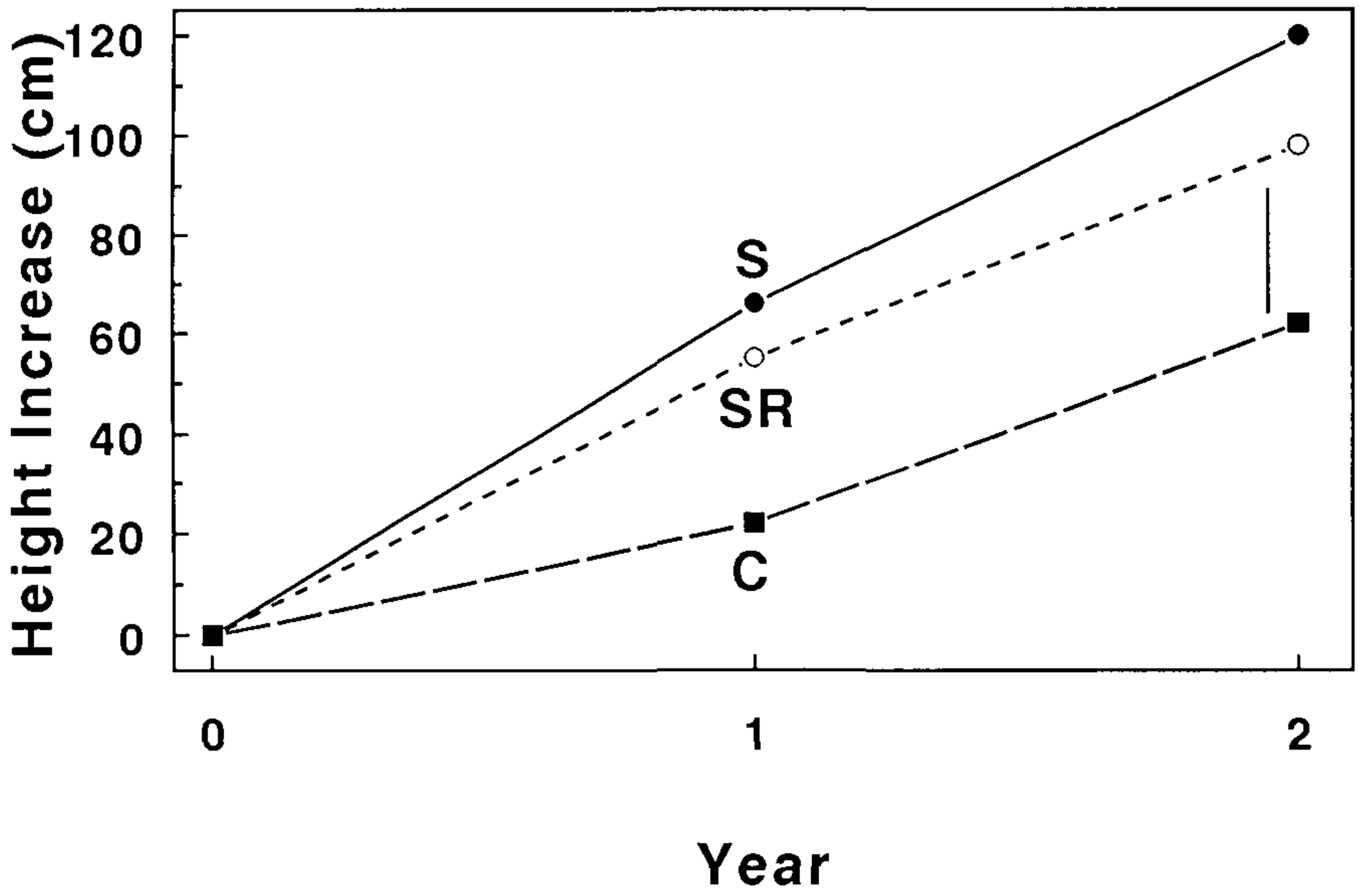

Figure 1. Height increase of redwood trees over a two-year period growing in treeshelters (S and SR treatments) and without shelters (C) under different irrigation regimes. Vertical bar represents 1 Standard Error.

tically significant. Neither treeshelters nor watering schedule had a significant effect on caliper, although in the second growing season, the control trees had about 26% to 31% greater caliper than those in treeshelters.

CONCLUSIONS

The growth responses of container-grown plants in our study indicate that treeshelters have an application in the nursery. The acceleration in tree height is attractive enough to encourage nursery managers to try slow-growing or grafted woody plants in treeshelters. Questions remain related to root development and transplantability of trees grown in shelters in the nursery. These are currently being addressed.

The landscape experiment with one-year-old redwood seedlings suggests that these trees, if planted by standard procedures, successfully establish themselves whether grown in treeshelters or not.

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Physiological Testing of Plants as a Management Tool

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Practical techniques have been developed for measuring root growth potential, cold hardiness, and other physiological attributes that are important to successful nursery practice and reestablishment of woody nursery stock. The techniques are described and their use in management illustrated. Woody plants are routinely grown in nurseries, shipped to a remote location, and then reestablished where they will remain for the rest of their life. Lifting, storage, shipping, and outplanting are traumatic events in the life of trees or shrubs; they must be in good physiological condition to withstand these treatments if they are to become reestablished and grow.

REQUIREMENTS FOR SUCCESSFUL LIFTING, STORAGE, AND REESTABLISHMENT

For fall lifting and cold storage, woody plants must be fully dormant or in "deep rest." In this condition they are best able to tolerate loss of roots, mechanical handling, and moisture and temperature stresses. The condition of deciduous trees and shrubs can be gauged by the normal abscission of their leaves, but evergreens do not show readily visible changes.

Plants need a certain degree of cold hardiness, at least enough to withstand cold storage and the conditions they will encounter on the site where they are outplanted. Equally important, cold hardiness is a good indicator of overall hardiness and stress resistance.

After outplanting, the plants must grow new roots to become established. How quickly this is necessary depends on the moisture stress at the planting site, which includes not only soil moisture but humidity, air temperature, and wind. Note that this applies to horticulture as much as it does to forestry. For example, it is usually possible to water horticultural plants after outplanting, and yet a plant's access to water is still limited, if its roots are not actively growing.

WHAT TO MEASURE AND HOW

The requirements described above suggest four physiological tests that will indicate the ability of the plant to perform as desired. These are bud dormancy, root growth potential, cold hardiness, and heat stress tolerance. As the plant progresses through its annual growth cycle, these attributes change according to a regular pattern. They are related one to another, fortunately, because some attributes, such as bud dormancy, cannot be measured quickly. However, by knowing the relations between the various attributes one can use a quickly measurable one such as cold hardiness to estimate the others (Tinus et al., 1986).

Bud Dormancy. Bud dormancy is usually measured by placing the plants under favorable growing conditions and observing the number of days until bud break (Lavender, 1985). Most temperate and boreal zone woody plants require a

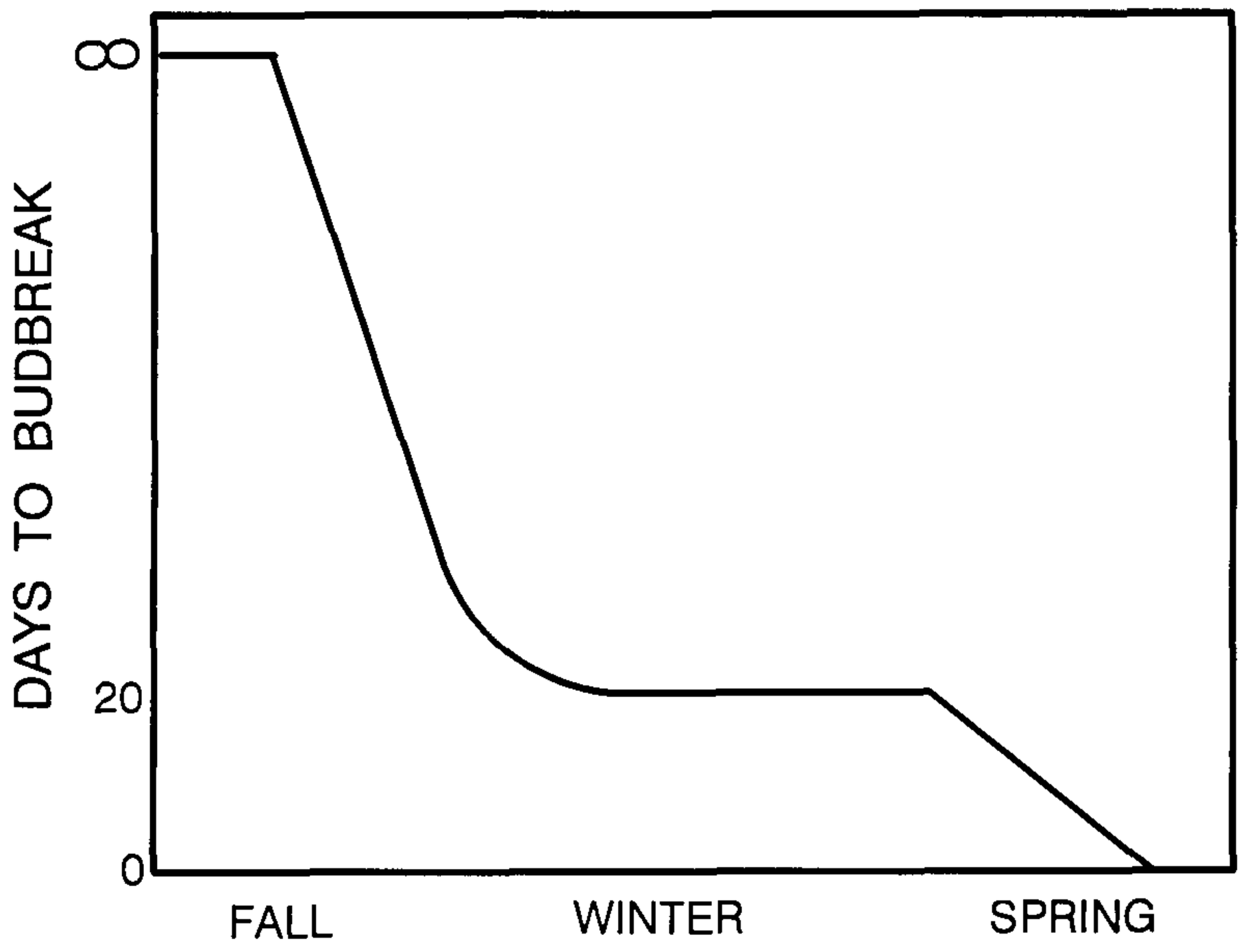

Figure 1. General pattern of days to bud break when woody plants are moved from outside into forcing conditions.

characteristic period of chilling before they will break bud. At first, buds typically take a long time to break, if they break at all, but as chilling progresses, days to bud break declines until it reaches a plateau (Fig. 1) at which there is no further progress toward bud break until warm weather comes. Maximum rest in southwestern conifers (Burr, 1990) occurs about when the chilling requirements have just been met. Although useful in research, measuring days to bud break takes too long to be a useful management tool.

Root Growth Potential. Root growth potential is measured by the number of new roots produced by a plant in a given time under favorable conditions (Ritchie, 1985; Rietveld and Tinus, 1987). Although there are three methods in use, the best is the mist chamber technique (Burr et al., 1987), which in its simplest and most versatile version is a chest freezer with its lid removed. The plants to be tested are suspended from tree holders with their roots exposed to the air in the chest, which contains about 15 cm of water in the bottom. An impact sprinkler mounted on a sump pump resting in the water and controlled by a timer periodically splashes water against the sides of the freezer, scattering small droplets of water throughout the chest, keeping the roots moist and the air at 100% relative humidity. Aquarium heaters in the bottom and the cooling system of the freezer control the temperature.

The root growth potential test is usually run for 7 or 14 days, at which time the new roots are counted on each plant. Absolute numbers of roots vary with species and size of plant, but within these limitations root growth potential will vary dramatically with stage in the annual growth cycle and the condition of the plant. Typically, root growth potential is low in late summer and rises in the fall. In Douglas-fir the rise is gradual and steady, but in Engelmann spruce it is abrupt;

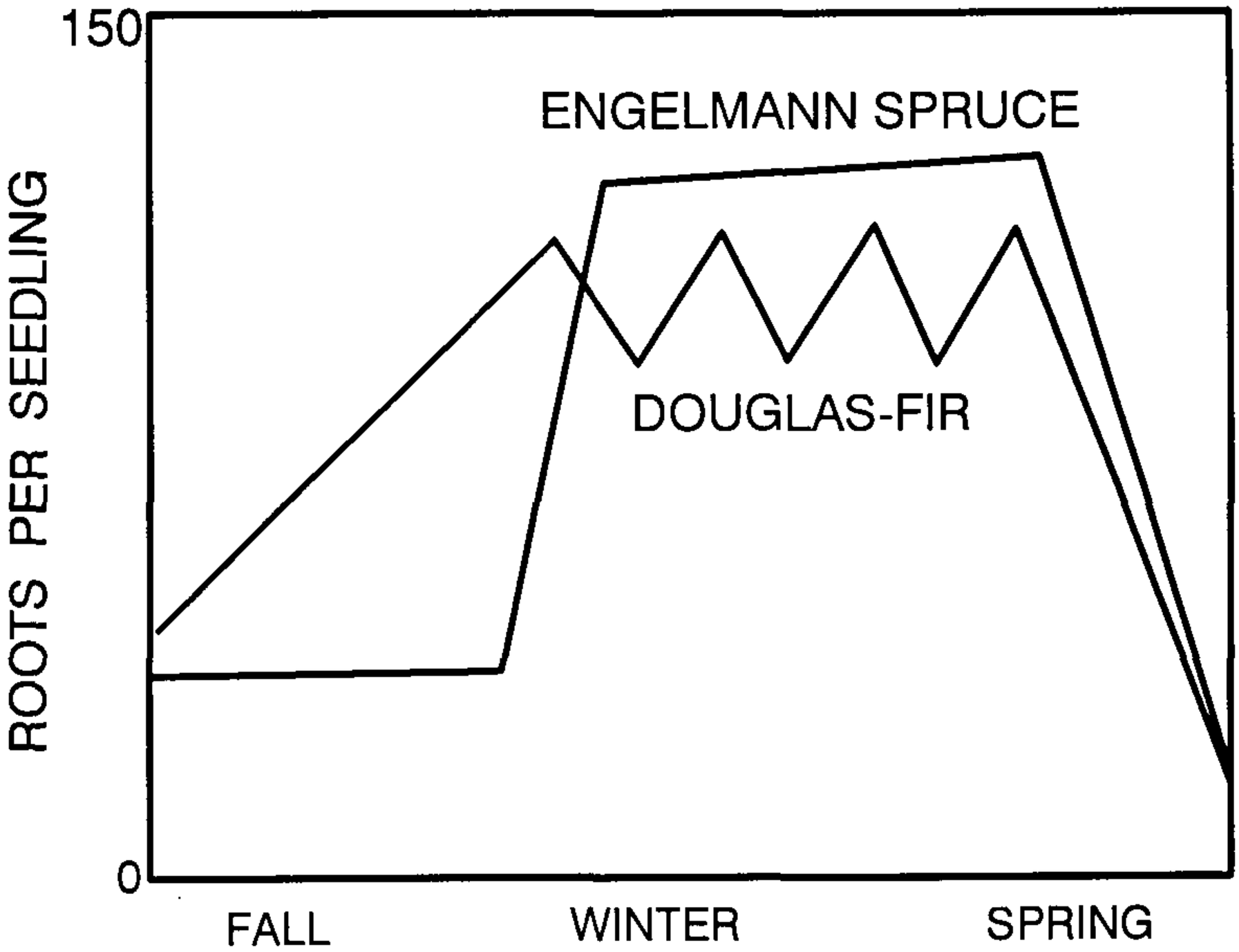

Figure 2. Engelmann spruce and Douglas-fir show different patterns of root growth potential during the dormant season.

it may rise by a factor of four in one week. Root growth potential remains high throughout the winter, may peak in the late winter, and falls to a low level as bud break approaches (Fig. 2).

How does root growth potential affect nursery management practices? It needs to be high when trees and shrubs are outplanted, so (1) it must be high going into storage, and (2) it must not be lost before the plants are back in the ground. The time to begin lifting in the fall is after root growth potential has risen. Normally root growth potential will remain high in cold storage, but it is more likely to decrease than increase (Burr and Tinus, 1988).

Cold Hardiness. Maximum cold hardiness of well adapted vegetation is almost always more than enough to prevent damage from cold during the winter. The critical times are more likely to be in the fall when the plant must harden in a timely manner, and in late winter and spring when it must not lose its hardiness prematurely. Although cold hardiness per se is usually not a problem, it can be measured quickly and, besides being a good measure of overall hardiness, can be used to estimate bud dormancy and root growth potential when a quick answer is important. Several good tests are available (Burr et al., 1990). In the "whole-plant freeze test" potted plants are placed in the bottom of a warm chest freezer, the roots insulated with vermiculite, and the freezer turned on. Once below freezing, the temperature should not fall more than 5°C per hour. At a series of successively lower benchmark temperatures a sample (usually one pot) is removed and placed in a cooler to thaw. After all of the samples have been removed and thawed, they are placed in a warm room or greenhouse. After 7 days the plants are examined for damage and the LT_{50} estimated. Actually, if you have a sensitive nose and with a

little training, you can smell the damage on conifers about 30 min after the plants are brought into a warm room.

The whole-plant freeze test is the one against which all others are calibrated, but a faster and more quantitative test is "freeze-induced electrolyte leakage". Foliage samples are placed in vials with a small amount of distilled water and frozen to a series of successively lower temperatures. At each benchmark temperature samples are removed and thawed. After incubation the conductivity of the solution is measured and an index of injury calculated. The greater the damage to the tissue, the more electrolytes leak out, and the greater the conductivity of the solution. This test can be completed in two days and does not destroy whole plants, but needs to be calibrated against the whole-plant freeze test.

Other tests are available and under development, but the two mentioned above are probably the best for management use now. Cold hardiness is least in the late spring, low throughout the summer, and begins rising (the LT_{50} temperature declines) in the early fall, reaching a maximum in early winter. It remains high until warm weather comes in the spring when it declines rapidly (Fig. 3).

Probably the greatest value of cold hardiness testing is in what it can tell about seedling quality. For example, when the LT_{50} in Rocky Mountain ponderosa pine, Douglas-fir, and Engelmann spruce has reached -22°C in the fall, the chilling requirements for bud break have been met, and root growth potential has doubled or more from its late summer low level. In the spring, when two thirds of maximum cold hardiness has been lost, root growth potential peaks and then declines rapidly as bud break approaches. In this case, cold hardiness is an excellent "leading indicator" because it changes measurably weeks before root growth potential is lost and long before there is any sign of bud break.

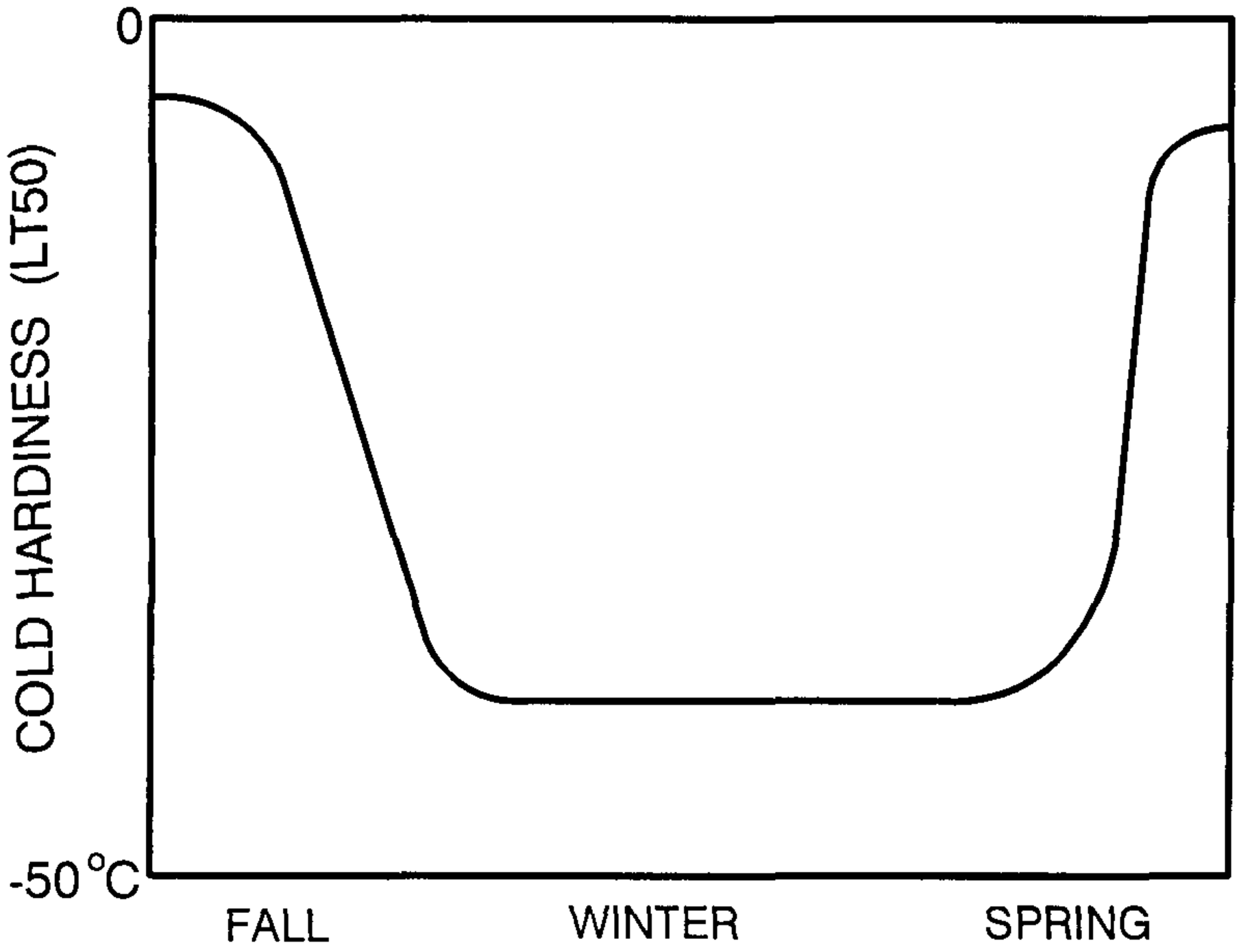

Figure 3. Normal pattern of cold hardiness during the dormant season. However, warm periods during the winter may cause premature de-hardening.

HEAT STRESS TEST

Although good nursery managers do everything possible to avoid high temperatures and desiccation, it is useful to know how much plants will withstand. In the "heat stress test" bare root plants are placed in a forced air drying oven at 32°C and relative humidity of 30% for 15 min. Then they are potted and placed in a greenhouse for several weeks along with some that have not been stressed. Survival and growth of both groups are noted and the difference is a measure of the tolerance for heat and desiccation stress (Duryea, 1985).

THE CASE OF THE FROZEN TRUCK

Usually, physiological tests are used to time cultural practices, monitor plant quality, and provide baseline information, but sometimes they can provide hard data needed for management decisions in a crisis.

In February 1991 a semi-truckload of tree seedlings was received at a National Forest District in Flagstaff—solidly frozen. The refrigeration on the truck apparently had stuck on. The question was: Were these trees damaged and should they still be planted? At stake was about $28,000 worth of trees plus at least that much to plant them. A go or no go decision had to be made in a matter of weeks.

Fortunately, one of the boxes of trees contained an electronic temperature recorder. During the three-day trip from Idaho the temperature in the box declined rapidly, reaching a low of -28°C, which was probably low enough to damage the shoots of the ponderosa pine and certainly low enough to kill the roots. The nursery had tested the seedlings before shipment, and cold hardiness was adequate and root growth potential high.

We retrieved samples of seedlings from two nearby districts that received trees in the frozen truck and from two districts that received trees from a different truck that functioned normally. We tested the four lots for root growth potential and cold hardiness, and the results were as follows:

District	Roots per seedling (mean ± std. error)	Mean % of root system dead
Truck OK		
A	18.4 ± 2.9	0
B	10.2 ± 2.5	0
Truck frozen		
C	1.3 ± 0.7	66
D	0.0 ± 0	86

Clearly, based on the root growth potential test, the trees in the frozen truck were badly damaged and were considered not worth planting.

The benchmark temperatures in the whole-plant freeze test were from -7°C to -23°C and should have shown any lack of adequate cold hardiness. After 14 days in the greenhouse, all of the "frozen truck" trees from all five test temperatures showed about equal damage to the stems and needles, indicating that the damage was preexisting and not caused by the freeze test.

As a result of these tests, the entire truckload of 160,000 trees was dumped. Six

years ago, before we had these tests available, the dead trees probably would have been planted, because managers would not have been willing to take responsibility for destroying the trees without good evidence that they were not viable. In addition, the nursery equipped that truck with a whole new $11,000 refrigeration system, something that would not have been done if there were any doubt about what the problem was and how serious it was.

In conclusion, physiological testing can provide valuable information for management decisions about the condition of woody plants and their prospects for survival and growth, especially during the dormant season when their condition is not obvious by inspection.

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Two Practices to Help Ensure Nursery Tree Quality

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Root pruning and care during the first transplantings of tree seedlings, as well as maintaining a central leader, are essential to ensure quality trees with strong branch structure. An open-ended polyester liner holds promise to minimize root problems and to enhance seedling growth.

INTRODUCTION

Two all-too-common nursery practices must change. Too many inferior quality trees have been and are being produced, sold, and planted in public and private landscapes. Landscape managers and maintenance people are realizing that quality planting stock is key to plant performance and ease of maintenance. Nurseries should realize that tighter and more objective nursery-tree specifications are being required by an increasing number of public and private buyers (Harris, 1992). These two practices are: (1) maintain a central leader with branches smaller than the trunk to ensure strong structure of mature trees, and (2) root pruning and careful transplanting from seed flats and/or liners to minimize kinked and circling roots.

Pruning. Many broadleaved trees, particularly those grown in containers, are headed to force several laterals close together to produce a young tree which appears dense and well proportioned. The branches, however, are too close together and near the same size. Trees so pruned seldom redevelop a new leader.

With no leader and branches near the same size, tree structure is weak. As large-growing trees mature their branches become large and more spreading. These trees are more subject to losing branches even in relatively calm weather. Few people ever realize these hazards started in the nursery. Few landscape maintenance people, even park and street tree workers, are aware of the problems of branches too low, too close together, and weakly attached until it is too late to correct without mutilating the tree. This has to stop.

Branches that could become permanent main scaffolds should be spaced vertically along the trunk. Potential scaffolds should be kept two-thirds (2/3) the trunk diameter or less. To ensure strong branch attachments, relative size is more important than angle of attachment. If the leader is headed, a new one should be developed.

Producing Quality Root Systems. The seedling liner and how it is handled is critical in producing vigorous trees free of kinked and circling roots. Seedling transfers from seed flats to liners and on to larger containers or from liners to larger containers are critical to the future well-being of a tree. All too often roots are kinked and circling which, if not prevented during these steps, can doom trees to poor growth or failure 5 to 15 years later.

MATERIAL AND METHODS

Nursery studies conducted more than twenty years ago are instructive. The common practice was to seed in flats, move the seedlings to peat pots, on into gallon cans, and finally into larger containers. Experiments compared root pruning versus no root pruning and times of transplanting from the seed flat and from liners (Harris et al., 1971). Species known to frequently have root defects in the landscape were used: *Eucalyptus sideroxylon* A. Cunn, ex Woolls (red ironbark), *Pinus radiata* D. Don (Monterey pine), *Pistacia chinensis* Bunge (Chinese pistache), and *Quercus ilex L.* (holly oak).

In one group of plants the seedlings and the liners were moved without the roots being pruned; in another the roots were pruned so that the seedlings could be placed into 2¼-in. peat pots without bending the main roots, and at the second move, the roots extending through the peat pots were removed before the plants were placed in gallon cans.

Table 1. Effects of root pruning on the structure of the root system and plant survival through the first growing season.

		Ironbark	Oak	Pine	Pistache
Number of trees per treatment [1]		416	180	288	128
Percentage of trees with good root systems:					
	Unpruned [2]	40	4	48	22
	Pruned	86	91	94	80
Percentage of trees with root defects:					
Kinked	Unpruned [2]	44	30	30	32
	Pruned	10	8	3	18
Kinked & circling	Unpruned [2]	14	66	20	46
	Pruned	2	1	1	2
Cricling	Unpruned	1.7	0	2.3	0
	Pruned	1.9	0	2.4	0
Percentage of survival in the field:					
	Unpruned	96	98	99	90
	Pruned	96	97	98	96

[1] Trees for the root evaluations were those in gallon cans examined at the end of the growing season. Survival was determined then also.

[2] Results for unpruned and pruned significantly different at the 0.01 level.

Groups of seedlings were transplanted at different stages of root development. The seedlings were first moved when the roots had reached the bottom and had grown along the seed flat bottom 1 to 3 in. The first moves from the seed flat were 5 to 10 days earlier than normal practice.

All the plants were grown in a glasshouse through the liner stage, then moved to the field after they were transplanted to gallon cans. Roots penetrated the moist peat pots with little difficulty. At the end of the growing season, the plants were measured and their roots were washed clean and rated as to the amount of kinking and circling.

RESULTS

Root pruning and care in transplanting significantly increased the number of trees with good root systems (Table 1). Root pruning during the two moves reduced the percentage of plants with seriously kinked roots, as well as those with roots both seriously kinked and circling. Few plants had only circling roots regardless whether the roots were pruned or not. In other words, the kinking of roots led to their circling.

For the oak seedlings in peat pots, only at the latest time of transplanting did root pruning result in less caliper and height growth compared to unpruned oaks or those pruned when moved earlier. Survival was not affected by root pruning of any of the species.

DISCUSSION

The kinking and circling occurred close to the surface and close to the trunk or main roots. Neither of these conditions can be easily corrected later. On the other hand, these conditions could be greatly reduced by pinching the roots at the first move and essentially breaking the crisp roots from the outside of the peat pot by running a finger around and under the pot. Each action took only one or two seconds.

The common practice now is to use plastic liners with little or no attention to root condition when moved into the next size container. Attempting to correct root circling when taken out of a plastic liner is time consuming and disruptive of the root ball. Whether corrective measures are taken or not, the results are all too obvious.

My recommendation was going to be, "Return to using seed flats and peat pots, move early, root prune, and take care in transplanting." This is still a sound recommendation. However, there is a promising alternative.

PROMISING ALTERNATIVE

Ron Motz and Janet Bozzo of All-Seasons Wholesale Nursery near Elk Grove, California, have developed a simple, unique procedure to germinate, transplant, and grow seedlings with little or no root disturbance or slowing of growth. At the present time they are concentrating on oaks.

An oak acorn is seeded in an open-ended cylinder of transparent polyester film (which had not met quality standards for x-ray use) filled with nitrified fir bark. The cylinder is placed in an open-bottom tray with other seeded cylinders for seed germination and seedling growth. The open bottom of the cylinder allows for air pruning of the roots as they reach the bottom of the cylinder.

As the roots begin to reach the side of the cylinder but before the roots can hold

the soil-mix together, the cylinder, soil mix, and seedling are "planted" in a 5- or 15-gal container. After firming the soil and watering well, the cylinder is pulled up to leave the root system essentially undisturbed. The soil is firmed and rewatered.

Revval blue polyester film (polyethylene phthalate polymers) is formed into a cylinder and held by two staples. A variety of cylinder sizes have been tried from 2½- to 4-in. diameters and 8 to 14 in. tall. At present, the film for a 4-in. diameter by 8-in. tall cylinder costs about $0.07 and the labor to staple it about $0.03.

The growth of the seedlings in the cylinders and after transplanting to larger containers has been excellent if moved at the right time. Three- to five-foot seedlings in one growing season has been possible with many oak species.

Using a longer cylinder filled only half way with soil mix provides a tree shelter which can further increase early top growth. If the lower two inches of a cylinder is left in the soil when pulled up at transplanting into a larger container, an even taller shelter is available.

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Critical Wind Blowdown Studies for Container Crops Using Cal Tech Wind Tunnel Facilities

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Critical wind blowdown studies were conducted in the Cal Tech wind tunnel with woody ornamental stock in various container sizes and with different plant spacing configurations. The study was conducted to assist in evaluating properties for relocation of a nursery and to determine how plant form, size and plant spacing influence the ability of wind to knock plants down and the wind velocity necessary to do this. Critical wind blowdown velocities ranged from 8.2 mph (3.9 m s^{-1}) for 1 gal (2800 cc) *Lagerstroemia indica* shrubs of 42 in. (106.7 cm) in height to 38 mph (18.1 m s^{-1}) for 5 gal (15,600 cc) *Ilex vomitoria* 'Stoke's Dwarf' bush forms.

INTRODUCTION

A literature search on wind blowdown studies on container stock revealed that no research has been done on the subject. In order to better evaluate properties for relocating Monrovia Nursery, a study was conducted in the Cal Tech wind tunnel with various sizes of container stock and spacing configurations.

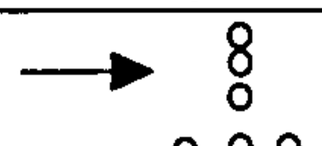
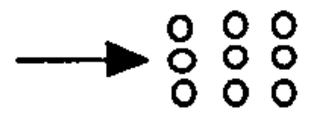
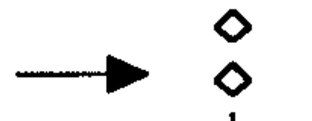
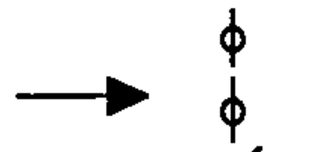
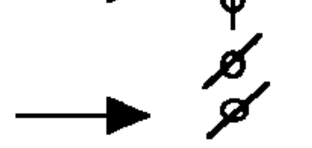
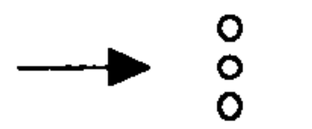
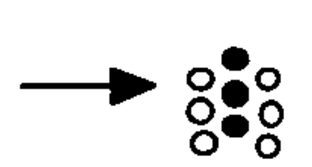
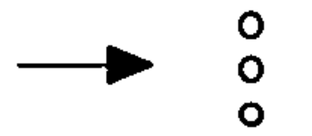
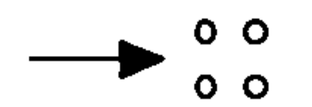
Nurserymen well know the cost and nuisance of picking up stock after it has blown over during windy periods. A knowledge of critical wind blowdown velocities will assist nurserymen in the placement and spacing of stock to minimize blowdown problems.

There are several wind tunnels at Cal Tech and at Jet Propulsion Lab, Pasadena, California. The Cal Tech wind tunnel used for these tests was built in 1928 and is still in use. It was instrumental in testing prototypes of the DC-3 (C-47) and was used until the 1950s by General Motors to test car bodies. The Cal Tech Guggenheim wind tunnel is capable of developing windspeeds of up to 200 mph (94.4 m s^{-1}). A second tunnel built in 1945 and modified in the mid 1950s is capable of developing windspeeds of 1.8 mach.

METHODS AND MATERIALS

Eighteen tests were conducted in the Guggenheim wind tunnel with gradually increasing wind velocities on 1-gal (2.8 liter) and 5-gal (15.6 liter) *Juniperus chinensis* 'Hetzii Columnaris'; 2-gal (6 liter) and 3-gal (10.6 liter) *J. chinensis* 'Robusta Green' in round containers and in 3-gal (10.6 liter) square plastic containers; 5-gal (15.6 liter) *Euonymus japonica* 'Grandifolia' espaliers; 5-gal tree *Magnolia grandiflora*, *Ilex vomitoria* 'Stoke's Dwarf', and *Hibiscus rosa-sinensis* 'Crown of Bohemia'; and 1-gal bush *Lagerstroemia indica*. The plants were arranged in either spaced single or double rows or as tight plants within rows, but spaced rows and with different orientations with respect to the wind. Wind velocities were gradually increased for each set of plants and configurations until the first plant blew down.

Table 1. Critical wind blowdown velocities for plants of different sizes and container arrangements.

Trmt.	Plant	Size & shape	Ht.[1] in.	Dia.[2] in.	Configuration	Wind → Container configuration	Critical blowdown velocity, mph.
1.	*J. chinensis* 'Hetzii Columnaris'	1	42	7	3 - 90° 3" bc		15.4
2.	"	1	42	7	9 - 90/180° 3" bc, 6" br		25.0
3.	"	5	60	12	3 - 90° 10" bc		20.2
4.	"	5	60	12	9 - 90/180° 3 x 3 10" br tbc		23.0 leaning 28.5 blowdown
5.	*J. chinensis* 'Robusta Green'	2	48	10	3 - 90° 10" bc		20.0
6.	"	3 RD	48	9	2 - 90° 10" bc		28.1
7.	"	3 SQ	48	9	2 - 90° 10" bc		25.5
8.	"	3 SQ	48	9	2 - 45° 10" bc		33.3
9.	*E. japonica* 'Grandifolia'	5 ESP	52	42	2 - 90° trellis near touching		9.5
10.	"	5 ESP	52	42	2 - 45°		12.1
11.	"	5 ESP	52	7	2 - 180°		20.2
					2 - 195°		19.6
12.	*M. grandiflora* 'Majestic Beauty'	5 TR	60	25	3 - 90°		15.0
13.	*M. grandiflora* 'Majestic Beauty' ● with *I. vomitoria* 'Stoke's Dwarf' ○	5 TR	60	25	3 - 90° 4"bc		16.1 outside
					6 - 90°		
		5 BU	22	17	3 x 2 10"		17.5 leaning on *Ilex*
14.	*I. vomitoria* 'Stoke's Dwarf'	5 BU	22	17	3 - 90° 10"bc		38.0
15.	*L. indica*	1 BU	42	21	3 - 90° 10"bc		8.2
16.	"	1 BU	42	21	6 - 90/180° bc 3 x 2 tbc,10" br		16.1
17.	*H. rosa-sinensis* 'Crown of Bohemia'	5 BU	48	22	2 - 90° 10"bc		27.9
18.	"	5 BU	48	22	2 x 2 - 90° 10" bc br		23.5

LEGEND:

1. height of container + plant
2. diameter of plant only

10" bc = 10" spacing between container
bc = between containers
br = between rows
tbc = tight between containers
bcr = between containers and rows
deg = container orientation to wind

E. = *Euonymus*
I. = *Ilex*
J. = *Juniperus*
L. = *Lagestromia*
M. = *Magnolia*
H. = *Hibiscus*

RD = round container
SQ = square container
ESP = espalier
TR = tree
BU = bush

RESULTS AND DISCUSSION

A summary of the results are listed in Table 1. The name of the plant is indicated, its size, the size of the container, the shape of the plant and of the container, the plant and row spacing, the configuration of the plants, and the critical wind blowdown velocity.

It is interesting to note that the force required to blow down upright conifers is greater in a block with spaced rows and tight cans within the row, than is required to blow down an isolated row of tight cans of the same plant. Wind flow patterns around plants are very complicated since the plants flex, changing the pattern of turbulence around the plants. In addition, air movement through the plants, influences the pressure zones and the eddies created. Apparently a pressure/turbulence zone is created on the back side of plants in a block which helps reduce blowdown if wind strikes at right angles to the rows. Compare treatments 1 and 2, and 3 and 4.

CONCLUSIONS

1) Square 3-gal containers blow over more easily than round containers if the wind hits the containers broadside. The round containers are more "streamlined aerodynamically." However, if you simulate the streamlining by arranging the square containers so that the wind hits them at 45°, it takes greater force to blow them down than it does the round container plants. (Table 1, treatments 6, 7, and 8).

2) As expected, the espaliers are most vulnerable to blowdown, especially if oriented in a way that greater surface area is exposed to the wind at 90° (Table 1, treatments 9, 10, 11, 12). It takes the same force to blow down an espalier at 180° to the wind as it does to blow down an upright conifer.

3) A much greater force is required to "tip" over magnolia trees interspersed with low bush-type 5-gal plants. The magnolias were prevented from completely tipping over because they leaned on the low growing 5-gal stock within 4 in. of each other.

4) It took the greatest amount of force (38 mph) to blow over 5-gal *I. vomitoria* 'Stoke's Dwarf'. It would probably take a similar force to knock down 5-gal conifer spreaders such as *J. tamariscifolia*, *J. chinensis* var. *procumbens* 'Nana', *J. horizontalis* 'Bar Harbor', etc.

5) It takes twice the force to blow over spaced rows of tight *Lagerstroemia indica*, than it does isolated spaced containers.

Effect of Slow-Release Fertilizers on Propagation Medium and on Rooting and Growth of Cuttings

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Two 17N-3.1P-8.1K (17-7-10) 12-14 month-release fertilizer formulations were surface applied at a rate of 0.5 lbs N/cu.yd. (22.58 g/1763 sq cm) to a rooting medium of peat and perlite (1 : 7, v/v) in comparison to peat and perlite (1 : 7, v/v) without fertilizer, and to composted sewage sludge and perlite (1 : 7, v/v). Cuttings of *Ilex* 'September Gem' showed a significant difference in the number of shoots produced per cutting between the two formulations. Cuttings in the fertilizer treatments were taller than the control. Composted sewage sludge in the medium did not produce better results than perlite alone. The number of roots and shoots per cutting and height of *Forsythia* × *intermedia* 'Spring Glory' cuttings was increased by the 3-4, 8-9, and 12-14 month-release Osmocote formulations as compared to the control. The largest cuttings occurred with the 12-14 month formulation.

INTRODUCTION

Extensive research has been carried out in recent years by a number of organizations throughout the world in development and evaluation of various slow-release fertilizers (SRF). Substantial experience and knowledge has been gained from this work and progress is still being made in this field. Interest by many people in SRF sources of plant nutrients is based on the recognition that conventional fertilizer programs are generally not very efficient (Barron, 1974); and SRFs are considered to be a potential means of optimizing crop yields with improved fertilizer efficiencies (Allen and Mays, 1974; Cardarelli, 1976; Russel and Williams, 1977).

A wide range of SRF materials with varying release rates are available for almost every type of crop (George, 1987). Various SRFs have characteristics that improve fertilizer efficiency and optimize plant nutrition. These long lasting fertilizers have significant effects on root dry weight, shoot dry weight, flower bud break, stem caliper, and growth index in various ornamental and forestry plants (Furuta, 1976; Torres, 1987; Przeradzki and MacCarthaigh, 1988). SRFs are especially effective for producing container nursery stock due to the limited nutrient and water holding capacity of soilless media and leaching from porous mixes, particularly of nitrogen and potassium (Ticknor, 1979 and Smith et al., 1991). In addition, the use of only one application of SRF for an entire growing season is very appealing (Sharma, 1979).

The purpose of this study was to: (1) determine the effect of two 12-14 month release products and three rooting media on rooting and subsequent growth of *Ilex*

cuttings, and (2) determine the effect of three slow-release fertilizer formulations with different release rates on the rooting and subsequent growth of *Forsythia* cuttings.

MATERIALS AND METHODS

The experiments were carried out in a glass-covered greenhouse at Oregon State University (OSU), Corvallis. The greenhouse is equipped with a mist irrigation system.

Experiment 1. (*Ilex* 'September Gem'). Cuttings were inserted in 2.25 in. × 3.25 in. pots on October 18, 1991 with six pots per replication and 12 replications. There were four treatments in the trial: (1) peat and perlite (1 : 7, v/v), (2) peat and perlite (1 : 7, v/v) plus Osmocote 17N-3.1P-8.1K (17-7-10) 12-14 month release rate, (3) peat and perlite (1 : 7, v/v) plus Helena 17N-3.1P-8.1K (17-7-10) 13.3 month release rate, and (4) composted sewage sludge and perlite (1 : 7, v/v).

Fertilizers (Osmocote and Helena) were applied to the surface of pots at the rate of 0.5 lb N/yd^3 or 22.58 grams of 17N-3.1P-8.1K (17-7-10) to a 1763 cm^2 (272 in.^{2}) area containing 48 pots. Treatments 1 to 4 were then randomized in the flats with two replications of six pots of each treatment in a flat.

The cuttings were wounded by removing basal leaves, dipped in 10% Wood's Rooting Compound (1013 ppm IBA plus 510 ppm NAA) for 5 sec, and stuck in 2.25-in. square × 3.25-in. deep pots. The flats were then placed on greenhouse benches equipped with mist irrigation. Mist intervals were 3 sec every 5 min from 8 a.m. to 6 p.m. daily. Roots were rated on March 24, 1992 when the maximum number of cuttings were rooted. A five-number scale was used in this observation on the basis of pot surface covered by roots: 0= dead, 1= no visible roots, 2= roots up to 1/4 of pot surface, 3= roots up to 1/2 of pot surface, 4= roots more than 1/2 of pot surface.

After rating roots, cuttings were shifted to 4-in. pots at North Willamette Research and Extension Center (OSU-NWREC), Aurora and were grown on capillary beds. Number of shoots per cutting was counted on April 24, 1992. Length and width of cuttings were measured on July 9-10, 1992.

Experiment 2. (*Forsythia* × *intermedia* 'Spring Glory'). This trial was started on April 2, 1992. Four six-inch cuttings with at least three internodes and similar stem thickness were taken from a single plant at OSU-NWREC, Aurora. The propagation medium was perlite. Three formulations of Osmocote with different release rates, all supplying 0.5 lb N/cu^3 of medium, were surface applied before inserting cuttings. Treatments were: (1) perlite without fertilizer, (2) perlite plus Osmocote 17N-3.1P-8.1K (17-7-10) 12-14 month release, (3) Perlite plus Osmocote 18N-2.6P-9.8K (18-6-12) 8-9 month release, and (4) Perlite plus Osmocote 19N-2.6P-9.8K (19-6-12) 3-4 month release.

Treatments 1 through 4 were randomized in each flat with two replications per flat. The same procedure was used for preparation and sticking of cuttings as in the case of *Ilex* 'September Gem'.

Length of liners was recorded on April 19, 1992. Roots were rated on May 26, 1992 when the maximum number of cuttings were rooted. Number of shoots per plant was recorded on June 27, 1992.

The experiment was carried out as a randomized complete block design with fertilizer formulations and type of medium as the main effects. Data was analyzed

using General Linear Model (GLM) procedure of SAS. The Fisher Protected Least Significant Difference (FPLSD) test was used to compare the differences between data means.

RESULTS AND DISCUSSION

Osmocote 17N-3.1P-8.1K (17-7-10) significantly increased the number of shoots and height of *Ilex* 'September Gem' cuttings as compared to the control (Table 1). No significant difference in roots per cutting, plant height, and plant width was noted between plants which received Osmocote and Helena 17N-3.1P-8.1K (17-7-10). However, plants receiving Osmocote produced more shoots per plant as compared to Helena. Composted Sewage Sludge (CSS) had no beneficial effect when included in the rooting media.

Table 1. Effect of 3 SRFs on growth performance of *Ilex* 'September Gem' cuttings treated with 1013 ppm IBA plus 510 ppm NAA on 10/18/1991 (6 plants per treatment with 12 reps).

Growth parameters	Evaluation date	Osmocote 17N-3.1P-8.1K (12-14 month release)	Helena 17N-3.1P-8.1K (13.3 month release)	Composted Sewage Sludge	Control
Roots/plant	3/24/92	3.6 a[1]	3.6 a	3.0 b	3.5 a
Shoots/plant	4/24/92	4.0 a	3.3 b	1.6 c	1.6 c
Plant height (cm)	7/9/92	19.0 a	19.0 a	16.2 b	17.1 b
Plant width (cm)	7/10/92	5.4 a	5.7 a	4.5 a	4.4 a

[1] Means in same row followed by the same letter are not significantly different at 0.05 level using FPLSD test.

The effects of three Osmocote formulations on growth performance of *Forsythia* cuttings as compared to a control are shown in Table 2. All three Osmocote formulations increased the number of roots and shoots per plant compared to the control. Furthermore, the use of the 12-14 month formulation 17N-3.1P-8.1K significantly increased the number of shoots per plant compared to the other formulations by 4½ months. These results are consistent with those of Gibson et al. (1977), Ward and Whitcomb (1977), Carlson and Preisig (1981), and Whitcomb (1983).

The three Osmocote formulations used in this study had different release rates. In addition, the release in relation to initial application also varies. The 19N-2.6P-9.8K (3-4 mo) has a rapid initial release rate (Sierra Chemical Company Milpitas, California 95035). The 17N-3.1P-8.1K (12-14 mo.), by contrast is slower to initially release than 19N-2.6P-9.8K and 18N-2.6P-9.8K. Much of the nutrients released by these shorter-term fertilizers are leached out and lost since during the first 2 to 3 weeks, and cuttings have limited ability to take up nutrients. It appears that the Osmocote formulation (17N-3.1P-8.1K) with the slowest initial release rate (12-14 mo.) is better suited for top-dressing on the surface of propagation media under mist irrigation systems.

Table 2. Comparison of Osmocote formulations on the growth of *Forsythia intermeida* × 'Spring Glory' treated with 1030 ppm IBA plus 510 ppm NAA on 4/2/92 (7 plants per treatment with 10 reps).

Growth parameters	Evaluation date	Osmocote 17N-3.1P-8.1K (12-14 month release)	Osmocote 18N-2.6P-9.8K (8-9 month release)	Osmocote 19N-2.6P-9.8K (3-4 month release)	Control
Plant height (cm)	4/19/92	13.1 a[1]	9.7 b	11.4 ab	6.9 c
Roots/plant	5/26/92	3.5 a	3.5 a	3.5 a	3.1 b
Shoots/plant	6/27/92	8.2 a	7.1 b	7.0 b	4.0 c

[1] Means in same row followed by the same letter are not significantly different at 0.05 level FPLSD test.

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An Overview of Integrated Pest Management for Plant Propagation

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IPM AND PLANT PROPAGATION

The following conditions and considerations should be considered when implementing an IPM program in a propagation facility:

- When plants are in close proximity; pest damage can be extensive
- Pest infestations are seeded as plants are put into production
- Pest infestations are sent with the plants to other producers
- Generally fewer pests and smaller greenhouse and nursery areas are involved
- Wet conditions (misting) presents unique problems

Arthropod Pests of Plants in Propagation. Mother block, tissue culture, and rooting areas are subject to attack from the following arthropod pests:

Common name	Species	Plants attacked
Thrips	*Frankliniella* & *Thrips* spp.	All plants; tissue culture
Fungus gnats	*Braydesia* spp.	Rose, bedding plants, greenhouse crops
Leafminers	*Liriomyza trifolii*	Marigold, verbena, chrysanthemum, etc.
Whiteflies	*Trialeurodes* & *Bemisia*	Poinsettia, verbena, ageratum, etc.
Beet armyworm	*Spodoptera exigua*	Chrysanthemum, etc.
Snails and slugs	*Helix aspersa* and many other species	All plants
Citrus mealybug	*Planococcus citri*	Coleus, kalanchoe, etc.
Black vine weevil	*Otiorynchus sulcatus*	Euonymus, etc.

Thrip Control in Plant Tissue Culture. *Allothrips* has been found as a contaminant in cultures of proliferating shoots of jojoba. Orthene at 10 and 100 ppm in the basal tissue culture media provided 100% control with no phytotoxicity observed. Autoclaving at 121°C. did not breakdown the pesticide (Klocke and Myers, 1984).

FUNGUS GNATS: *BRAYDESIA COPROPHILA* OR *B. IMPATIENS*.

Identification. Fungus gnats are small delicate flies with long legs, a 'Y' shaped vein in each wing, and long beaded antennae. Larvae are worm-like, small, translucent to white, with a distinct black head capsule.

Damage. Adults can be a nuisance, however, larvae feed on young roots and root hairs.

Biology. Eggs are laid during dim periods of light in clusters in cracks on the soil surface. They hatch in 7 days and four larval stages develop in 2-3 weeks. The young larvae feed in groups with soil fungi the main diet. The larvae pupate under the soil surface in a silken cocoon; adults emerge in 7 days, mate and lay 75 eggs in 3 to 5 days of adult life. They are weak flyers and prefer to run. They cannot survive on root hairs and roots alone.

Control Strategies.

l) Cultural methods include:

- Sanitation
- Weed control
- Under bench treatments (hydrated lime at 1.5 lb/gal water or copper sulfate at 1 lb/gal water) (Check on registration uses of these products in your state or country)
- Soil mixes
- Avoid over watering/wet greenhouses

2) Biological Control

- Some promising results with nematodes, but large numbers must be released

Use of Nematodes For Control Fungus Gnats and Other Root Feeders. Commercially available nematodes include *Steinernema* sp. and *Heterorhabdus* spp. in association with the bacterium *Xeizorhabdus* spp. They are suggested for control of black vine weevil larvae, fungus gnats, and other root feeders in pots. In the U.S., Exhibit can be used at the rate of one package per 10,000 sq ft at 7 day intervals—at least 3 applications are required.

IPM

IPM is the intelligent selection and use of actions that will insure favorable economic, ecological, and sociological consequences. It includes the integration of many pest control techniques (cultural, physical, mechanical, political, chemical and biological). Well-defined or mandated IPM programs may be the future for local production and for imports/exports.

IPM Can no Longer be Ignored. Most greenhouse managers/horticulturists have had extensive training in plant production but limited education in control of plant pests. This lack of plant pest control knowledge leads to conservative management strategies—the application of pesticides. The knowledge of an insect's biology can lead to better management strategies using all the tenets of IPM.

IPM must be viewed as part of the overall production system used in the greenhouse. Arthropod and disease control must be considered along every step in the crop production process—IPM strategies in the propagation phase are critical. Unless this is done, growers will continue to be reacting to pest problems in a conservative manner which is no longer acceptable. In addition, it is becoming more and more difficult to achieve successful control.

Pesticides will always be important for pest control in aesthetic-value crops; however, a definite move away from hard pesticides is occurring. If you rely heavily on pesticides to keep your crop/propagation area clean, you have problems ahead. IPM will allow growers to survive the changing pesticide scene and still produce a high quality crop.

WHAT IS THE ORIGIN OF YOUR PEST PROBLEMS?

Knowledge of the origin of your pest problems enables you to become proactive in dealing with pest problems rather than reactive. Possible sources include: contamination of propagative material, migration into the greenhouse, plant material already in the greenhouse, contaminated mother block or propagative areas, and contaminated greenhouse structures.

The detection and appropriate action needed to control such sources include:

Source	Detection Method	Appropriate Action
Propagative material	Inspect a % upon arrival	Contact propagator; preproduction treatment
Migration	Use yellow/blue cards outside and inside the greenhouse	Screening; weed control outside the greenhouse
Greenhouse plant material	Yellow cards; visual plant searches	Treat; discard; planning location of next crop
Mother block	As above	As above; preproduction or propagation treatments; screening areas
Contaminated structures	Inspection; pest and severity	Disinfect prior to next crop

TENETS OF IPM

Monitoring. Monitoring is an essential aspect of any IPM program. It includes: using sticky cards both inside and outside the greenhouse; setting thresholds appropriate for your operation; inspecting plants for the presence of insects using a regular and defined sampling program (concentrate on sensitive cultivars); keeping accurate and timely records; and making use of sentinel plants for evaluation of chemicals and biocontrol.

Cultural Aspects. Cultural aspects include: proper sanitation and weed control inside and outside the greenhouse (western flower thrips and leafminers); avoiding excessive fertilization (aphids and leafminers); and avoiding wet spots in the greenhouse (fungus gnats).

Host Plant Resistance. While this is not a panacea it can be important. Make use of the knowledge of host plant resistance/susceptibility: eliminate sensitive cultivars; plant sensitive cultivars away from vents, doorways, etc., monitor sensitive cultivars more closely (early detection); and possibly spot treat (chemicals, natural enemies).

Physical/Mechanical Control Methods. Propagation areas are usually easier to screen because of their small size. Examples of such methods include: soil sterilization between crops; use of screening; and modify greenhouses to have a double door entry system.

Management of Pesticides. The proper management of pesticides is a very important and integral part of any IPM program. Proper management includes: the appropriate selection of pesticides; the proper application equipment, correct timing of pesticide sprays (efficacy and compatibility, proper rotation of chemicals); effective tank mixes; and preproduction treatments.

Building an IPM Program. University/extension personnel can offer a blue print for an ideal IPM program. It will be unusual for a grower to be able to put all the tenets of this "ideal" program into practice. The grower must chose what can be implemented based on the particular operation (no two IPM programs will be the same). The resources available are critical but the grower must be committed to the concept.

Reasons for Reducing Pesticide Use.

1) Less hazardous to the environment
2) Fewer problems with insecticide resistance
3) Fewer problems with phytotoxicity: stress
4) Loss of registered materials; few new registrations
5) Minimal risk to workers and the general public
6) Increasing compatibility with natural enemies
7) Cost is increasing; economics/liability
8) Confusing, conflicting, and ever-changing regulations
9) Municipalities may be able to set their own regulations
10) The pesticides used on imported flowers may be more tightly controlled in the future

Biological Control. There are still more questions that research must answer, but rapid strides are being made. Pathogens may be the only recourse in the future for some pests. An integrated approach utilizing the proper selection of pathogens; choosing compatible pesticides; deciding on threshold levels (imports vs. local consumption); and becoming knowledgeable about the pathogens you are using (symptoms of infection, spread, etc.) will characterize a well-balanced IPM program.

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Making the Change to Integrated Pest Management

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INTRODUCTION

Little information has been written about the use of Integrated Pest Management (IPM) in ornamental nursery production systems. Nursery professionals wishing to establish an IPM program must adapt methods used on greenhouse crops or urban landscapes to their production methods. Nursery IPM is complicated by the fact that the plants do not remain stationary; they move from propagation to liners to gallons and eventually to retailers and the landscape. Mobile host plants make it complicated to track pests and difficult to restrict their spread. It is also harder to establish a balanced system of predators and parasites as is done in greenhouses, orchards, or urban landscapes.

At the University Arboretum the plants produced in our small nursery (approximately an acre) have two general destinations: the campus landscape collections (including the Arboretum) and our annual fund-raising plant sale. Plants destined for distribution to the public are treated much as they would be in a commercial nursery with one exception—all production labor for propagation, repotting, labeling, pruning, and fertilization is provided by a dedicated corps of volunteers. To protect our volunteer work force, some 30 regular volunteers ranging in age from 4 to 75, we needed to eliminate as many hazards to them as possible. This motivated us to seek an IPM program using least-toxic pest control methods.

Information gained in our situation is most applicable to smaller nurseries. Our crop is very diverse with relatively small numbers of each species rather than the large blocks found in larger wholesale nurseries. However, the techniques and treatments we've used, which are the basis of many IPM programs, can be useful regardless of the size of the nursery. From our experience we have learned that to make the change to an IPM program a nursery must make three basic organizational changes in terms of management, personnel, and record keeping.

MAKE THE MANAGERIAL COMMITMENT TO IPM

When converting to an integrated system of pest control, staff must view the crop and production area as a biological system and act not only to eliminate pests but also to protect beneficial insects. This can be achieved by incorporation of physical, cultural, and biological controls into the pest control program. Beneficial parasites and predators will be aided by using least-toxic chemical controls. Accompany good monitoring and use of spot sprays (rather than cover sprays) with selection of insecticides with short residual action. These practices will increase the likelihood of preserving unsprayed refuges for your beneficials and will also decrease the likelihood of development of pesticide resistance in your pest populations. Make sure your tactics are compatible; pesticides should be selected which will have the least affect on predators present. Abandon the "see and spray" method by using your monitoring records to set action thresholds for each pest. Table 1. presents some of the action thresholds we use for pests in our nursery. Decide which pests you have zero tolerance for and which might be tolerable at low levels to provide

food and host species for beneficial insects while causing little damage to the economic value of your crop.

Table 1. Some action thresholds for pest treatment.

Pest	Treatment threshold
Aphids	Presence of alates (winged aphids) and nymphs (zero tolerance on *Dianthus*—viral vectors)
Whitefly	Presence of eggs indicated by waxy deposits.
Thrips	Presence on smaller plants in greenhouse.
Mites	As soon as detected.
Lacebug	Presence of pest.
Mealybug	Presence of pest.
Leafhoppers	Treat only immediately prior to sale.
Plant bugs	Spray only when damage (stippling) becomes obvious
Flea beetles	Spray only when damage (stippling) becomes obvious

ALLOCATE FUNDS FOR TRAINED PERSONNEL

Unless you already have an entomologist on staff you will need to hire a specialist to gather information about the insect pests, predators, and parasites, as well as appropriate pesticides for your crops. This specialist will need to distinguish between the beneficial and harmful insects. Proper identification is essential, as well as knowledge of pest behavior, and the effect of weather, temperature, and pesticides on pest populations. Establishment of monitoring routines can best be done by a professional who has been trained to do so. Monitoring and spot spraying is initially more expensive than calendar cover sprays because monitoring is labor-intensive. However, we have found that careful monitoring and timing of applications will reduce total pesticide usage as well as the number of applications needed and result in future labor savings.

DEVELOP A SIMPLE RECORD KEEPING SYSTEM

Keep careful records of the pests (identification and density), hosts, beneficials, and the date of occurrence. You need to build a body of knowledge useful for prediction under your particular circumstances. We have found this information very useful for catching infestations early before they become difficult to control. We use a simple flat-file database (Wordperfect Notebook) to record the above information as well as comments, the plant location and treatments used.

SEAT OF THE PANTS IPM

Our three-year-old program has been developed by the "seat of the pants" technique and is founded on those basic methods, cited above, common to most IPM programs: careful and consistent monitoring, written records, establishment of action thresholds, the use of yellow sticky traps, pesticide baits (for ants), and low-toxicity, low-residual pesticides such as insecticidal soap, *Bacillus thuringiensis*, and pyrethrins. This summer we are testing two new products, Sunspray, a new light oil, and Pyrenone, pyrethrin with a synergist, for efficacy and phytotoxicity. The U.C. Davis graduate program in Plant Protection and Pest Management (PPPM) has supplied the excellent student interns who have provided their expertise and labor setting up our program. We have also been fortunate to have the advice and interest of the staff of the U.C. IPM Education and Publications group. The first season, March through September 1990, was spent developing monitoring forms, recording pest/host occurrence, treating infested plants, and observing the effectiveness of less-toxic pesticide use. A big change we made that year was the abandonment of Dursban for control of ants in favor of Grant's Ant Stakes (an arsenic bait). Also, because of its shorter residual, pyrethrin was substituted for the synthetic pyrethroids previously used. The second season, during the summer of 1991, the recorded data from the previous year allowed us to predict the sequence of pest outbreaks and the expected degree of infestation. We improved our insect identification and reference collection and continued to test the effectiveness of control while limiting ourselves to soaps, pyrethrin, and *Bacillus thuringiensis*.

BENEFICIAL INSECTS

In 1992 we noticed a dramatic increase in naturally occurring populations of beneficial insects such as lady beetles, syrphid flies (sometimes called hoverflies), predatory mites, wasps, and spiders. We believe this to be caused by the elimination of long-residual pesticides, specifically the use of the organophosphate, Dursban, for Argentine ant control. This year, for the first time, we incorporated the use of inundative releases of beneficial insects into our IPM program. Since our early season whitefly problems seem to originate in the greenhouse we made a mid-April release of *Encarsia formosa*. This parasitic wasp has established on some nurse plants and appears to move on to new plants as needed. Larvae of the green lacewing (*Chrysoperla rufilabris*) were released weekly for 8 consecutive weeks from April 1 to May 20th for the control of aphids. The beneficial predatory mite (*Metaseiulus occidentalis*) was released twice, May 28th and July 8th, for the control of two-spotted spider mites. Use of the lacewing larvae coincided with a dramatic reduction in aphids and at the end of the 8-week period we had great difficulty finding any aphids to treat. Our total soap use for April through June dropped from 227 oz in 1991 to 23 oz in 1992, a dramatic effect attributed in part to the reduction in aphids by the lacewing larvae and part to favorable weather conditions. A comparison of insecticidal soap usage for 1991 and 1992 can be seen in Figure 1. The early application (when pest mites were first observed) of predatory mites also appeared successful. Presence of pest mites has remained limited to only a few spots where the predators are still observed. *Metaseiulus* has also been seen around the nursery dining on white flies and thrips.

To attract and encourage beneficial insects to remain we have planted various nectar and pollen plants around the nursery to provide alternate food sources when

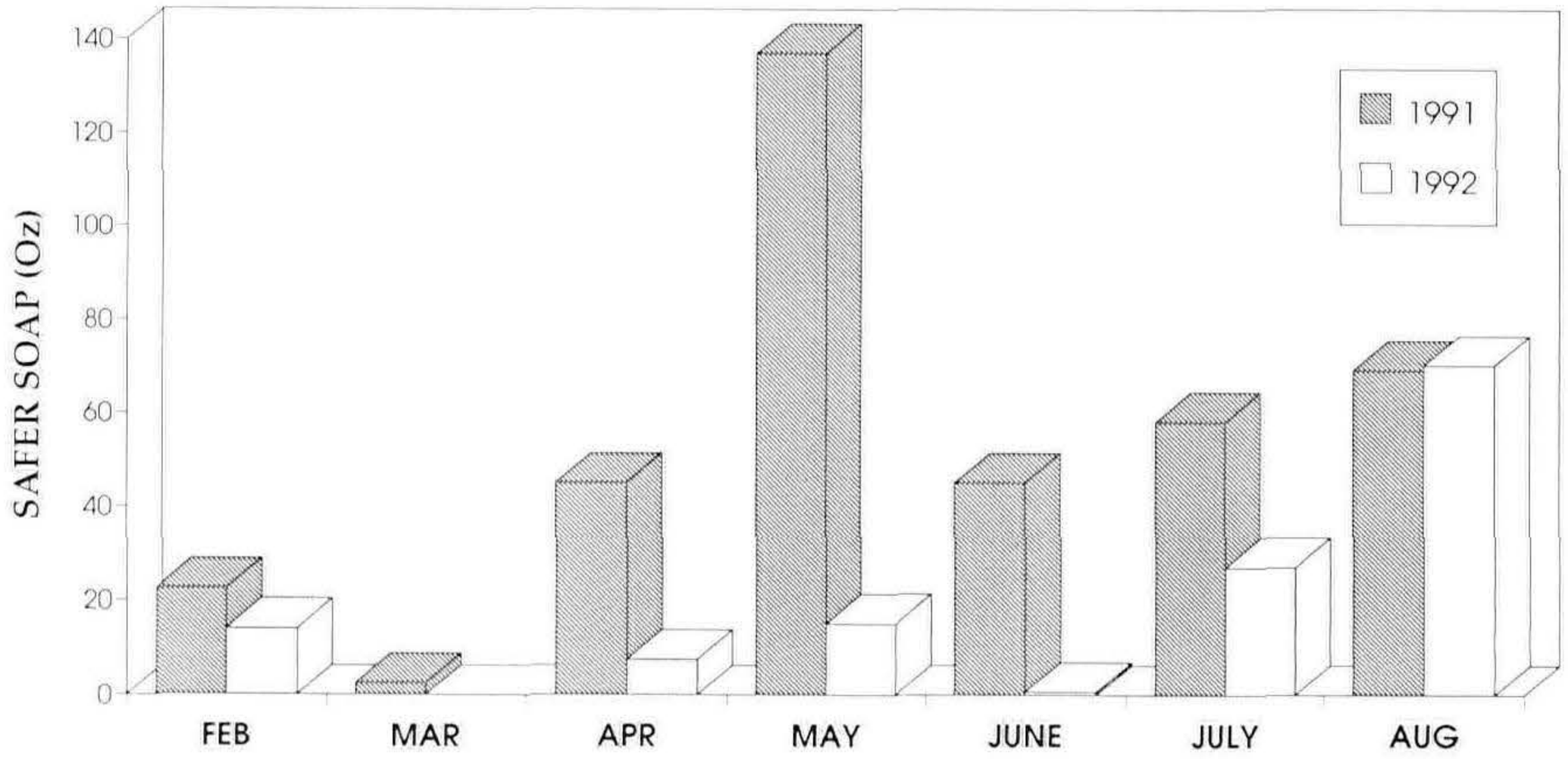

Figure 1. Total safer soap applied to arboretum nursery.

pest populations are low. Growing around the nursery are some shrubby native buckwheats, *Eriogonum giganteum* and *E. fasciculatum*; coffeeberry, *Rhamnus californica*; bronze fennel, *Foeniculum vulgare* 'Purpureum'; candytuft, *Lobularia maritima*; and the Chilean soapbark tree, *Quillaja saponaria*. An existing willow, *Salix bonplandiana* [syn. *S. laevigata*] at the nursery serves as an insectary plant when it becomes infested with the giant willow aphid, a pest specific to willow which does not spread, and which also serves as an alternate food source for beneficials. A commercial preparation of yeast, sugar and water (Bugpro™) was also applied to increase food availability when populations of adult lacewings were high.

REMAINING WORK

The changes we have made in pesticides have resulted in resurgence of some pests. A summary of major pests and control treatments can be found in Table 2. Attempts to control the obscure mealybug on species and cultivars of the genus *Heuchera* with the predatory mealybug destroyer (*Cryptolaemus*), soaps, and light oil have so far been unsatisfactory. Pyrenone, a pyrethrin with synergist, is currently being tested for efficacy against this pest and for possible phytotoxicity. Also, we are hoping to retest the application of *Cryptolaemus* for control, doing it earlier in the season next year. Lacebugs, leafhoppers, and flea beetles have proven resistant to our preliminary control efforts using soap and are also candidates for treatment with oil and pyrenone. These pesticides are under trial until we can incorporate more follow-up evaluation of control efficacy. Our methods have provided us with excellent control of aphids and mites, but we want to fine tune early season control of whitefly in the hope we can avoid high spray use in August and September. Next year we hope to explore the use of degree-day calculation in predicting pest outbreaks so we can better schedule the timing of pesticide sprays and release of beneficials. We also believe it worthwhile to try a release of the predator, *Thripobius luteus*, which attacks thrips to reduce the spraying necessary in the greenhouse.

Table 2. Major pests, treatments used, and evaluation of control.

Pest	Treatments used (in order of importance)	Control	Comments
Ants	Ant stakes	Acceptable	Stakes need periodic replacement, spot spray required late in season.
	Tanglefoot barriers		
Aphids	*Chrysoperla* larvae insecticidal soap	Excellent	Natural parasitism evident
Mealybugs	*Cryptolaemus* Pyrethrin Horticultural oil Insecticidal soap	Poor	Soap ineffective, others experimental
Thrips	Horticultural oil Pyrethrin Insecticidal soap	Acceptable	Soap reduced numbers only, others needed for good control
Whiteflies	Insecticidal soap Horticultural oil Yellow sticky traps	Acceptable	Eggs not effected by soap, earlier spray needed
	Encarsia formosa		In greenhouse only

Excellent=applications result in control.
Acceptable=repeat applications necessary for control.
Poor=control not achieved with listed method(s).

CONCLUSIONS

We feel that our IPM program works for us and hope that some nurseries may be able to apply the information here to their own production systems. The most important work that we have left undone is an economic analysis of our methods compared to more traditional pest control. Many nurseries will resist the change to IPM until it has been demonstrated to them that these practices will increase the net on their balance sheet. But regulatory withdrawal of some pesticides, increased costs of liability insurance, and stricter environmental regulations concerning offsite pollution are putting pressures on all in the industry to reduce highly toxic pesticides whenever possible. We believe it is worth a look and that nursery professionals who develop IPM programs will find that it pays off in the future.

Resources for Establishing an IPM Program for Ornamental Plants

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INTRODUCTION

Integrated pest management (IPM) is an ecological pest management strategy that focuses on longterm prevention or suppression of pest problems with minimum impact on human health, the environment, and nontarget organisms. Principal components include pest identification; methods for detecting, monitoring, and predicting pest outbreaks; a knowledge of the biology of the pest and its ecological interactions with hosts, natural enemies, and competitors; and compatible methods of preventing and managing pest populations. Preferred techniques include encouraging naturally occurring biological control, using alternate plant species or cultivars that resist pests or stock that is certified pest-free, selecting pesticides with lower toxicity to humans and nontarget organisms; adoption of cultivation, pruning, fertilizing, or irrigation practices that reduce pest problems; or changing the habitat to make it incompatible with pest development. Broad spectrum pesticides are used as a last resort when careful monitoring indicates they are needed according to preestablished guidelines. When treatments are necessary, the least toxic and most target-specific pesticides are chosen. IPM is a knowledge-based decision-making system, and an essential element is a well-trained and informed decisionmaker. Resources for establishing an IPM program are discussed below.

PEST IDENTIFICATION

Improper identification of pests or damage leads to many pest management mistakes. Similar-looking organisms may require quite different management actions; a pesticide, cultural practice, or resistant cultivar that controls one may not control the other. Even more importantly, organisms that closely resemble pests may actually not be damaging or may even be beneficial. When pesticides are applied to control a nonpest, not only is the problem not alleviated but the toxic materials may cause further injury to the system by inhibiting biological control or causing phytotoxicity. Sometimes insects, mites, or other organisms are incorrectly identified as pests because they occur on plants suffering damage from an unrelated cause such as overwatering, phytotoxicity, or disease. It is important to confirm that damage symptoms are the result of the organism targeted for control.

Anyone carrying out an IPM program should have a basic library to assist in identification of both pests and hosts. Managers working with woody ornamentals will find the Cornell publications by Sinclair et al. (1987) and Johnson and Lyon (1988) essential pest idenfication guides. The University of California Division of Agriculture and Natural Resources (UCANR) has two publications with color pictures of pests on ornamentals including Koehler (1987) for insects and Keim and Humphrey (1988) for pathogens. An IPM manual for woody ornamentals featuring over 250 color pictures of pests and damage is being produced in my office and will

be released before the end of 1993. Several general references with color pictures are available from UCANR including the Grower's Weed Identification Book, Pests of the Garden and Small Farm (Flint, 1990a), and the various-crop specific IPM manuals produced by the UC Statewide IPM Project. Another good source of assistance in identifying plant disease problems are the series of compendia produced by the American Phytopathological Society; currently they have publications on greenhouse crops (Jarvis, 1992), ornamental palms (Chase and Brochat, 1991), ornamental foliage (Chase, 1987), elm (Stipes and Campana, 1981), rhododendron and azalea (Coyier and Roane, 1986), rose (Horst, 1983) as well as compendia for many agricultural crops. Vertebrate pests are addressed in Salmon and Lickliter (1984). Insect and mite pests of interior plantscapes and glasshouses are discussed in Hussey and Scopes (1985) and Steiner and Elliot (1987); insects attacking many trees are described in Furniss and Carolin (1977). There are numerous general reference books for insects; one good one is Swan and Papp (1972). California propagators should be aware of the color keys for whiteflies, mealybugs, soft scales, and armoured scales (Gill 1982a, 1982b, 1982c, 1982d) produced by the California Department of Food and Agriculture as well as keys to aphids, thrips, mites, snails, and slugs (Kono and Papp, 1977). A key to ants is provided in Haney et al. (1987).

Some pest organisms can only be reliably identified by trained professionals. Do not hesitate to ask for help. Pathogens and nematodes can be particularly difficult to identify but insects and mites will also need to be sent to experts on some occasions. Try to identify local sources of expertise before problems crop up so you can be sure of getting the most rapid service. County departments of agriculture and university Cooperative Extension offices will help in identification or refer you to appropriate experts. Some private laboratories identify nematodes and pathogens for a fee. Obtaining the services of a well-trained and experienced pest management consultant may be the best way to assure ready access to reliable ID resources.

BIOLOGICAL/ECOLOGICAL INFORMATION

A goal of integrated pest management is to take advantage of the ecological relationships between host, pest, natural enemies, or the environment to sustain long-term suppression of pest problems with minimum hazard to the environment. Many of the publications listed in the section above on pest identification can give you some background for understanding the biologies of your crop plants and pests. General references on integrated pest management (e.g. Flint and van den Bosch, 1981) or crop management (e.g. Harris, 1983) can give you some basic ecological concepts. However, some of the most valuable information will be that you obtain yourself through regular monitoring of your plants and their pest problems. Always keep written records and monitor in a uniform manner so you can compare month-to-month or year-to-year patterns. Two computer programs available from the UC IPM Program, DDU, and TRAP, can help you predict pest growth based on temperature or keep and analyze monitoring data from traps.

MONITORING GUIDELINES/TREATMENT THRESHOLDS

A common denominator of all IPM programs is having a trained pest manager regularly (e.g. weekly or biweekly) check plants in a systematic manner for evidence of pests or other potential problems. A few specialized monitoring devices

are available such as pheromone traps for some moth pests and yellow sticky traps for whiteflies and leafminers, but generally monitoring involves visual inspection of leaves, bark, buds, or other plant parts. For some agricultural crops and a few ornamentals, University experts have developed guidelines based on these sampling results as to when pesticide treatment or other control actions are necessary. A few guidelines are outlined in publications reviewed under pest identification as well as in the UCIPM Pest Management Guidelines listed in the references (guidelines for ornamental crops will begin to be released in 1993). However, in many cases, pest managers in ornamental nurseries will have to develop their own guidelines based on experience and their knowledge of their clientele. What distinguishes IPM programs from conventional programs that require spraying at the first detection of a pest is the concept that minimum levels of some pests can be tolerated without economic loss. Our research in the University of California Davis Arboretum (Flint et al., in press) indicates that customers do not discriminate between plants with certain types of damage, and that establishing a monitoring program by a trained pest management scout can significantly reduce pesticide use with no loss of plant quality.

ECOLOGICALLY SOUND PEST MANAGEMENT METHODS

Preferred management methods in an IPM program are those that have minimum impact on natural sources of biological control, are least likely to induce pesticide resistance, are least likely to have negative human health or environmental impacts, yet provide effective long-term control. One very important but underutilized strategy in ornamental horticulture is the use of pest-tolerant cultivars. Too often cultivars are chosen without regard to pest resistance or are planted under conditions inappropriate for their vigorous growth, thus increasing their susceptibility to pests. Information about pest resistance and growing requirements should be available from your seed or propagation sources; keep records of your own experiences to supplement this information under your own growing conditions. Good introductions to the types of methods used in IPM programs are given in Flint (1990a), Olkowski et al. (1991), Henn and Weinzierl (1989, 1990), Weinzierl and Henn (1989), and Weinzierl et al. (1990). Many of the other publications listed in the references give specific recommendations for ecologically sound pest management techniques for specific pests. The California Environmental Protection Agency puts out a free list of sources of biological control agents (Hunter 1992). Twenty of the most common natural enemies are pictured in a poster (Flint, 1990b) from UC ANR publications. The Bio Integral Resource Center (P.O. Box 7414, Berkeley, CA 94707) puts out an annual list of IPM products and services; they also publish two publications, The IPM Practitioner and The Common Sense Pest Control Quarterly, that can keep you informed about new innovations in IPM. University Cooperative Extension offices offer expertise, publications, demonstrations, and workshops to help you identify IPM methods suitable for your operation; get on their mailing lists! Choosing pesticides that have the least impact on natural control and the environment should be an important element of your program. For insect and mite control, soaps, oils, and microbial pesticides are good selective choices where they are effective. Manufacturers can provide you with labels and MSDS sheets; a recent publication (Davidson et al., 1991) details the use of oils for controlling insect and mite pests. Croft (1990) reviews the research literature on impact of pesticides on natural enemies. Steiner and Elliot (1987)

summarize impact of pesticides on natural enemies commonly released in glasshouses. Marer (1988) discusses how to use conventional pesticides selectively and safely.

THE PEST CONTROL CONSULTANT

Initiating an IPM program on a commercial scale is a formidable task, especially for someone with little formal training in pest management. Flint et al. (1991) gives some idea of what is involved. At least at first, I strongly recommend contracting the services of an experienced IPM consultant, who is not involved in the sale or application of pesticides, or hiring a staff member with the appropriate expertise. The Plant Protection and Pest Management Masters Degree program at the University of California at Davis provides an excellent educational background, especially when supplemented with field experience. Several other universities in the U.S. offer similar programs.

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Recycling Green Nursery Waste

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Because landfills are filling at a rapid pace, many states have enacted regulations prohibiting or restricting the disposal of yard waste in landfills. Container nurseries generate about 60 yd^3 (46 m^3) of organic waste per acre per year (113 m^3 ha^{-1}). By grinding and composting these wastes a nursery can save in two ways: (1) it does not need to pay to dump the waste, and (2) it does not have to purchase organic matter for growing media. The return on investment can be as high as 171% within 3 years in California. Nursery waste has better C:N ratios than most organic matters and recycling these wastes also recycles the nutrients.

INTRODUCTION

Our landfills are filling fast and many states have enacted regulations governing disposal of wastes. For example, California has passed AB 939, 1820 and 3992, which requires that counties divert 25% of their waste from landfills by January 1995 and 50% by January 2000 (California, State of, 1990). Container nurseries generate about 60 yds^3 (46 m^3) of organic matter waste per acre per year (113 m^3 ha^{-1}). I foresaw some of the problems with disposal of nursery wastes, and I began to study the possibility of recycling these wastes in 1990.

Wastes of biological origin are compostable wastes. Compostable wastes generated by nurseries are prunings, scrap lumber, dead plants, weeds, old stakes, discarded plants, paper and cardboard. Organic waste generation by nurseries varies with the kind of crop grown and the turnover rate. In one study, it was found that a container nursery can generate 60 yd^3 of waste per acre per year (113 m^3 ha^{-1}). This waste can be ground and composted. After grinding, this volume decreases 20% to 72% depending on the kind of waste. Tub grinders, similar to the hay grinders farmers use — but much heavier duty, are used to grind wood and plant waste. Some of these grinders are built to grind tree stumps and logs. However, it is more efficient to use a chipper to cut up limbs having diameters greater than 1 in. (2.54 cm). Following chipping, the waste can be reground in a tub grinder. General prunings, paper and cardboard can be put directly into the tub grinder. There are numerous kinds of tub grinders on the market ranging in price from $12,000 to $350,000. Chippers range in price from $7,000 to $22,000. These costs may sound out of reach for nurseries, but the cost analyses I have done indicates otherwise. To stimulate recycling, California has provided a tax credit incentive of 40% of the cost of such equipment up to $250,000.

Many people have a fear of allelopathic chemicals in raw plant waste used as organic matter sources. Wastes such as eucalyptus, walnut, Brazilian pepper, cedar, and redwood have been considered allelopathic by many. We have been using redwood sawdust for many years with no problems. I recently conducted an experiment with eucalyptus, considered by many to be phytotoxic. In this test, I

used raw as well as composted eucalyptus in growing media. I had a mean relative growth of 93% in 100% raw eucalyptus waste growing medium compared with 105% relative growth in 100% composted eucalyptus waste. The check was composed of well-composted sawdust plus soil. An alternative treatment of 75% peat and 25% soil had 109% relative growth. There was a slight decrease in the growth in the 100% eucalyptus waste which may have been due to poor water relations since the medium was very coarse in nature and its water holding capacity was poor. Composting generally will decompose or render allelopathic chemicals inactive and the fear is unfounded. Composting should be considered standard practice.

Tipping or dumping fees for disposal of yard waste to landfills varies throughout the country. The average for the country is $25.60 per ton (Glenn, 1992). However, this fee does not include the cost of the rental of a disposal box which is kept on the property of the waste generator. In southern California, disposal costs vary from $3.17 to $7.00 per yd^3 (0.77 m^3). A nursery that grinds its wastes and composts them for reuse in growing media saves in two ways: (1) it does not have to pay a dumping fee, and (2) it does not have to purchase organic matter for its media. The savings can be substantial.

A side benefit of recycling waste is nutrient recycling. Ground nursery waste has a superior nutrient composition compared with sawdusts or peat moss (Table 1). Its C : N ratio is approximately 23 : 1. This ratio may vary depending upon the percent of prunings present in the waste. In contrast, the C : N ratio of raw sawdusts ranges from 315 to 1000 : 1; barks range from 274 to 490 : 1 and peatmoss ranges from 48 to 90 : 1.

Table 1. Chemical composition of ground nursery waste[z]

$Kgm^{3\,-1}$							
pH	DSm^{-1}	N	P	K	Ca	Mg	Fe
5.7	6.00	2.60	0.196	1.01	1.96	0.59	0.88
Mn	Zn	Cu	Na	B	Bd^y		
0.047	0.013	0.005	0.071	0.005	200		

[z]Extraction with 6N HCl, 16h
[y]Bulk density; dry wt

Because ground nursery waste has such an excellent C : N ratio, it composts quickly and there is no need to add additional N to the compost pile. Also, because of its nutrient content, the composting waste quickly reaches 155°F (68°C) which is important to kill pathogens and weed seeds.

THE ECONOMICS OF RECYCLING WASTES

A cost analysis of processing green waste indicates it costs $0.48 to 0.52 per yard (0.77 m^3) to grind nursery waste with a tub grinder. This includes fuel, labor, and maintenance. Because there is a reduction in volume between 20% and 72% after grinding, the cost to process a $yard^3$ (0.77 m^3) of ground waste in California is $1.71. However, if you compare this cost to what one has to pay for sawdust, bark or peat, the saving is great. In addition to savings created by not having to purchase organic matter for growing media, one can save the cost of disposal of the original waste. Since the original, unground waste is loose, much of that yard of waste is air. In California the cost varies between $3.17 to $7.00 per yard to dispose of that waste. The value of the organic matter plus the savings from not having to dispose of the waste, can be substantial. The potential savings per yard of processed waste may be $21.61/yd or more. Table 2 lists minimal waste disposal savings. These savings can be higher in different parts of the country or due to the method of disposal.

Table 2. Potential savings per yard (0.77 m^3) of processed waste.

Value of organic matter	U.S. $	12.00
Cost to process[z]		- 1.71
Waste disposal[y]		11.32
Total	U.S. $	21.61

[z] $0.48 divided by 0.28 (28% remaining in volume after grinding)
[y] $3.17 divided by 0.28

By using the formula:

$$\frac{\text{Cost of Grinder}}{(\text{VOM} \times \text{VR}) - (\text{CTP}) + \text{DFS}}$$

one can determine the number of yards of loose waste which must be processed to recover the cost of the grinder, where VOM = value of the organic matter, VR = volume remaining after grinding, CTP = cost to process and DFS = disposal fee saving. With this formula, 4,473 yd^3 (3420 m^3) of waste would have to be processed to recover the cost of a $27,063 grinder. A 25 acre (10.13 ha) nursery generating 60 yd/acre/yr (113m^3ha^{-1}) would recover the cost of the equipment in 3 years. The recovery of costs is comparable regardless of the size of the nursery, even if the larger nursery has to purchase a larger, more expensive grinder. In addition, the State of California offers a 40% tax credit for grinding equipment (California, State of, 1989). Consequently, a 100 acre (40.5 ha) nursery purchasing a larger piece of equipment costing $81,000 would realize a return of 171% on their investment in 3 years! This is a conservative estimate!

CONCLUSIONS

Recycling nursery green waste is a viable means to reduce our landfill loading and is economically rewarding for the nurseryman to do so. Because nursery waste comes from well-fed nursery stock, the nutrient composition and C : N ratios are excellent. Recycling the waste reduces the need to supply extra N to the composting process and reduces the demand for excessive N as is necessary with some highly carbonaceous growing media. Because nursery waste heats up readily to pasteurization temperatures, the need for fumigation of the organic fraction is eliminated.

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Water Conserving Irrigation Systems

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Many factors (sprinkler spacing, sprinkler performance, water pressure, wind, and others) combine to determine how efficiently and uniformly water is applied to plants growing in the greenhouse, nursery, or landscape. The myriad factors can be organized into the following categories: Pre-Design Considerations, Design Considerations, Irrigation System Modifiers, and Irrigation System Control. General guidelines have been used in the past to analyze irrigation systems and optimize the distribution of water. However, as energy and water conservation issues begin to play larger roles in the production and maintenance of ornamental plants, irrigation system analyses must become more precise to improve the uniformity of water application and increase the efficient use of available water.

PRE-DESIGN CONSIDERATIONS

Site Dimensions and Water Availability. Whether you are planning to irrigate a defined turf area or a number of plants growing in containers, you need to know the area and the area's shape where water is to be applied. This information will help determine your choices for the type of water emitter (sprinkler, drip). The water supply is also important in terms of quantity (volume) that is available and its pressure. Water quality is very important in that there is little that can be done to improve water once it arrives at your site. Water quality characteristics can be described in terms of electrical conductivity (EC), ion concentrations (Na^{+2}, HCO_3^-, Ca^{+2}, Cl^-), pH, and/or insoluble particulates.

Water Emitter Selection. Overhead sprinklers or some type of drip system may be used to irrigate plants in the greenhouse, nursery, or landscape. Drip (i.e. Chapin spaghetti) systems are used extensively to irrigate greenhouse crops, while in the outdoor nursery overhead sprinklers are used for can-tight crops and drip systems are reserved for larger spaced crops. Manufacturers of irrigation equipment can help growers decide on the type and placement of emitters for a particular area. Irrigation system design recommendations (spacing arrangement and distances) based on tests of sprinkler heads (emitters) placed at ground level to determine distribution patterns are generally available. In a nursery, sprinkler heads will typically be placed some height above the ground to avoid interference from the developing crop canopy. Raising the sprinkler head 40 in. above the ground can lead to interesting and significant changes in its distribution pattern. The difference in the distribution patterns of the same sprinkler at the same pressure at two heights, ground level and 40 in. above the ground, are shown in Figure 1. While it is interesting to note that the distribution patterns are different at the two heights, the important point is that the optimum spacing for the sprinkler head at the two heights is different.

Crop Requirements. Work at Davis and around California has shown that container-grown crops have differing requirements for water. Plants can be grouped into heavy, moderate, or light water user groups (Burger et al., 1987).

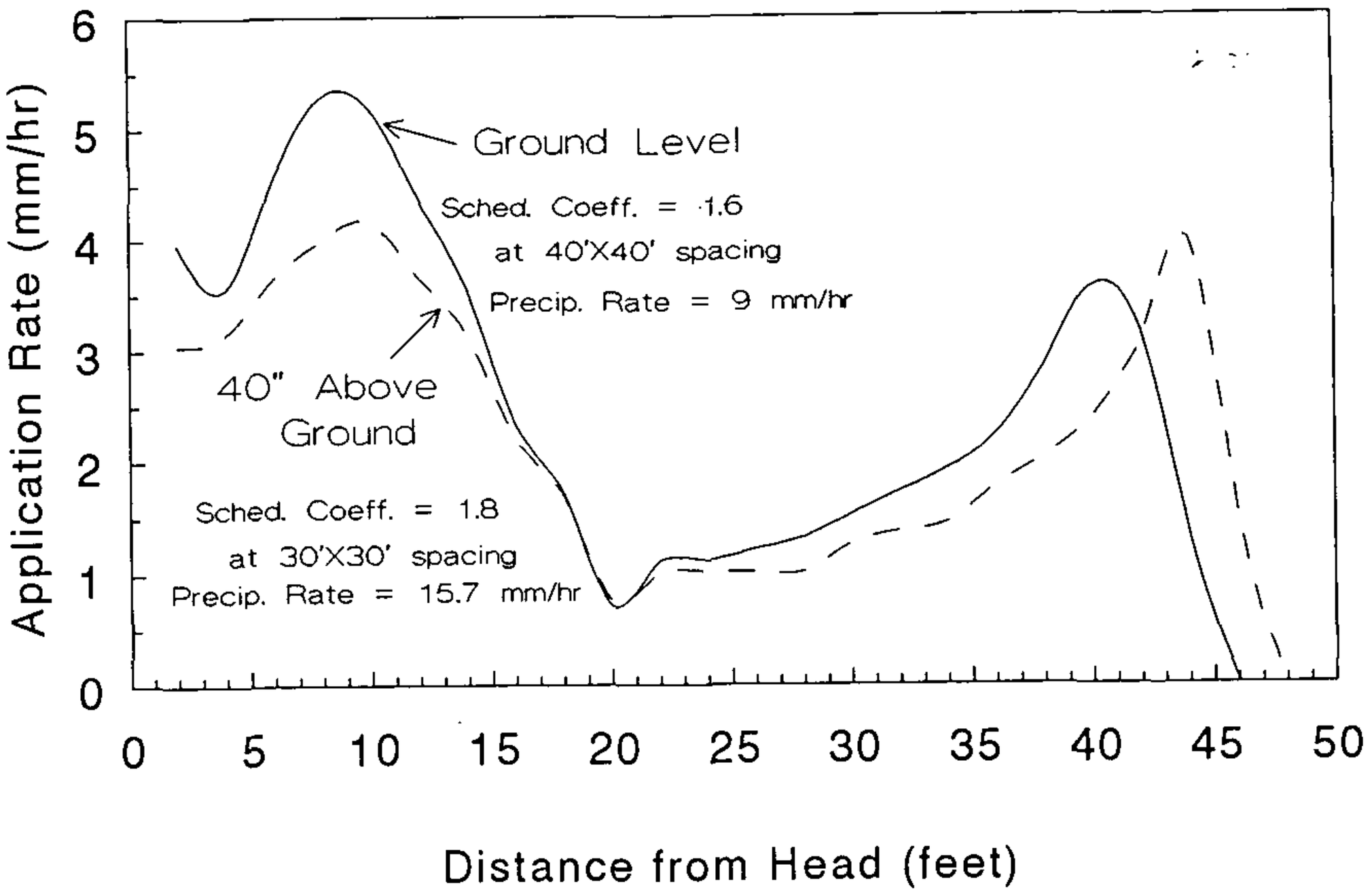

Figure 1. Distribution patterns of a sprinkler at two different heights (ground level and 40 in. above the ground).

Because the differences among species is relatively great in their respective requirements for water, it makes sense to locate those species having similar water requirements together and irrigate them similarly if not simultaneously.

The same plants growing in different climates will have different water requirements (Burger et al., 1987). Research done at Davis, Watsonville, the South Coast Field Station (Irvine), and San Bernardino, California indicates that by using ET_0 (reference evapotranspiration) as a basis, crop coefficients can be calculated that remain relatively constant among different environments.

A particular water requirement for a given plant can change as the plant develops. As the leaf surface area and root length density increases, the amount of water required to maintain the highest growth rate and quality also increases. Therefore, one needs to routinely monitor the water requirement of a developing crop.

Container Spacing. As container-grown plants grow, they are spaced farther apart to provide room for canopy development. The spacing of containers leads to increased solar radiation and increased temperature loads on the containers, thus increasing water use (transpiration) and loss (evaporation) (see Fig. 2). Even when containers are arranged "can-tight", all of the ground is not covered by the containers. One-gallon containers arranged "can-tight" cover only 79% of the surface, meaning 21% is left uncovered. Because the plants are arranged in beds, there are differences in the exposure of plants to sunlight and temperature between those plants in the interior and those on the borders.

DESIGN CONSIDERATIONS

Pressure Loss. The most important factor contributing to the uniform application of water is pressure. The quantity of water delivered by a sprinkler head (gallons

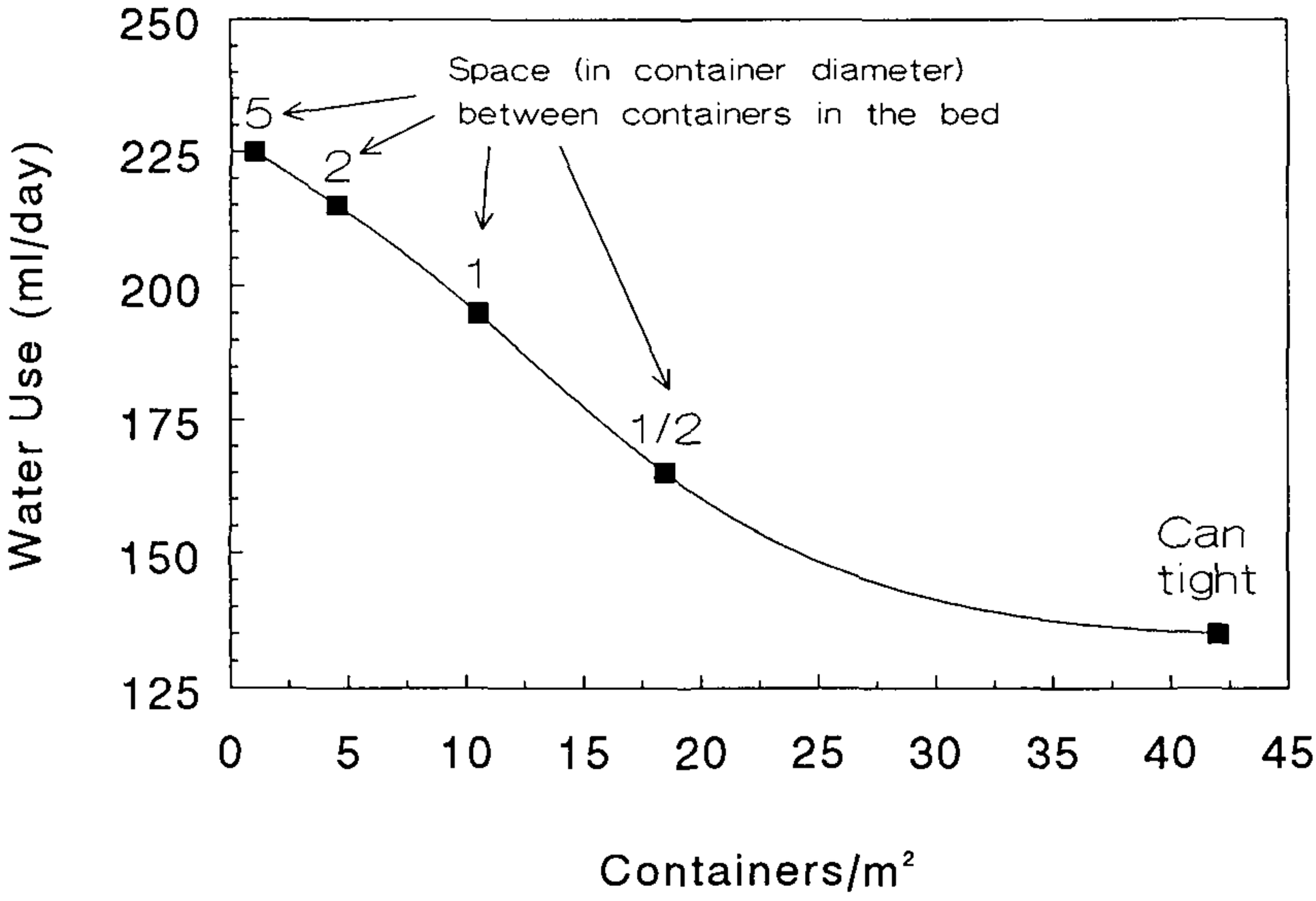

Figure 2. Water use (loss) characteristics of plants growing at different spacings.

per minute, GPM) is calculated using the following equation:

$$GPM = \sqrt{P \times D^2 \times C \times 29.82}$$

where P = pressure in pounds per square inch, D = orifice diameter of the sprinkler, in inches, C = coefficient of discharge for that sprinkler, and 29.82 is a constant. Variables D and C and the quantity 29.82 are all constant for any given sprinkler head; therefore, GPM is proportional to the square root of pressure. So, while the design of irrigation systems seems to be focused on the movement and control of water, a more important consideration is the control of pressure.

Uniformity of Water Application. The goal of any irrigation system is to apply exactly the same amount of water to every square inch or to every container. The degree of uniformity that is achieved by an irrigation system is usually expressed as the Coefficient of Uniformity (CU). The CU is determined by laying out a grid of cans (for example, every 5 ft in a square pattern) on the area being irrigated by a single system. The irrigation system is operated for a known period of time after which the accumulated water in each can (catchment data) is measured (volume in ml or cc). If the top surface area of the can is known, the application rate (in./h, mm/h) can be determined. The catchment data is used to calculate the average quantity of water per can. The CU is then calculated by the following equation:

$$CU = 100 \left(1.0 - \frac{\sum |\bar{x} - x_i|}{\bar{x}n} \right)$$

where $|x—x_i|$ = sum of the deviations of each observation (x_i) from the mean ($\bar{x}$-) of the observations and n = the number of observations. The CU has a maximum possible value of 100 which would indicate a perfectly uniform application of water. A CU less than 80 indicates a poorly designed irrigation system.

Application Rate. Catchment data can be used to determine application (precipitation) rates. The application rate is the average rate at which water is being applied to the area covered by the sprinkler layout. The application rate should be known for all irrigation systems. For drip or spaghetti systems the application rate can be measured by catching water from the system over a known period of time.

Scheduling Coefficient. The scheduling coefficient is another measure of uniformity. It is the ratio between the average precipitation rate (application rate) and the lowest precipitation rate in the sprinkler layout. Catchment data from can tests are used to calculate this value. The scheduling coefficient has a value equal to or greater than 1.0 and can be thought of as a multiplier to determine sprinkler system timing. For example, if the average application rate for a system was 12 mm/hr and the driest area had an application rate of 7 mm/hr, the scheduling coefficient would equal 12/7≈ 1.7. This means that if a group of plants required 9 mm of water per day, this irrigation system would have to be operated for 1.3 hours per day (1 h/12 mm × 9 mm/day × 1.7) to insure that all plants received an adequate supply of water. A scheduling coefficient closer to 1.0 indicates a more uniform irrigation system.

IRRIGATION SYSTEM MODIFIERS

Wind. The direction and velocity of wind in the area under sprinkler irrigation can drastically affect the uniformity of water distribution. To date, there is no one satisfactory answer to this problem; however, the problem can be minimized by operating sprinkler systems at recommended pressures and sprinkler head spacings.

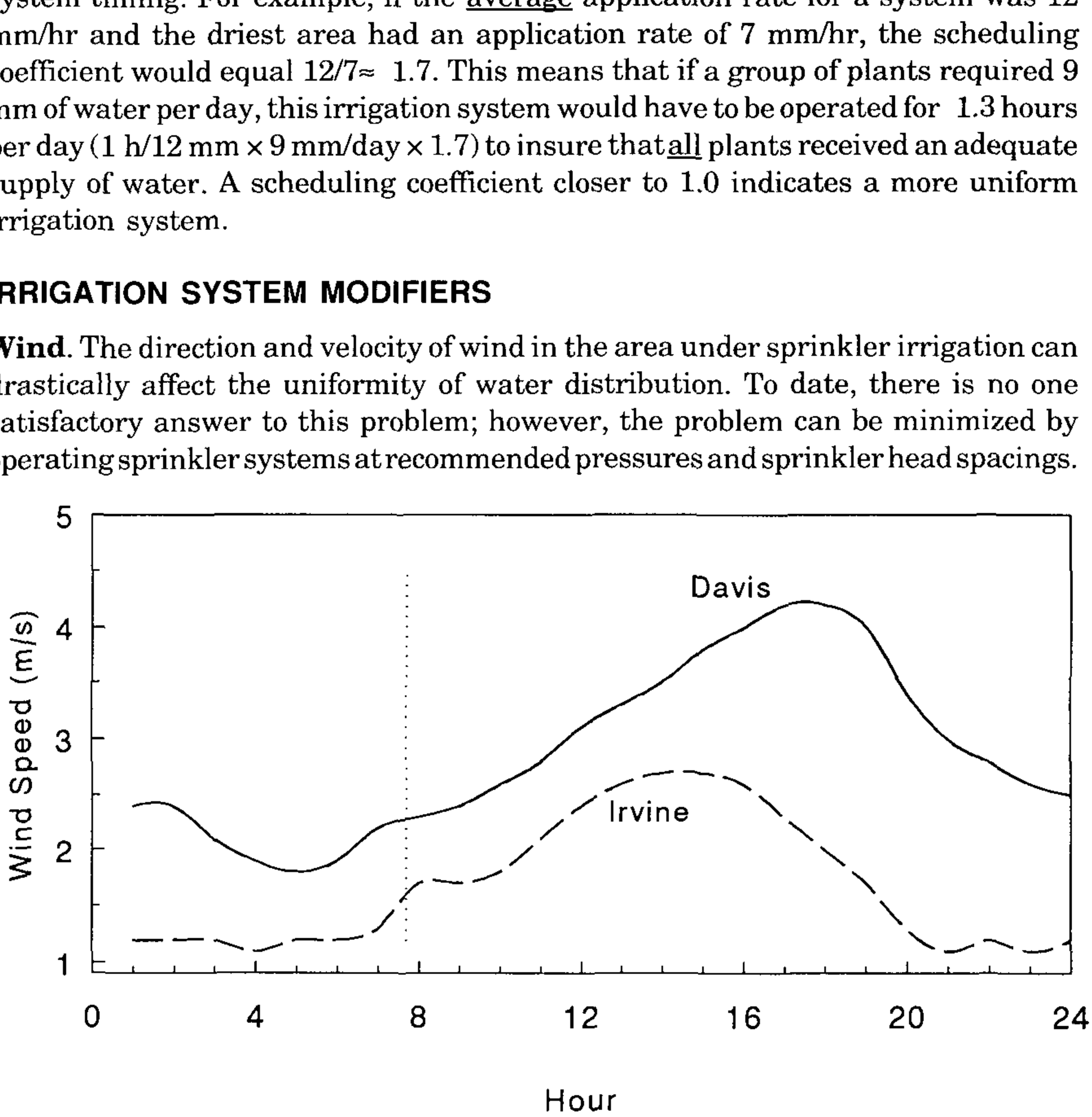

Figure 3. Average hourly wind speed from June 1-30, 1992 for Davis and Irvine, CA.

The best an irrigation manager can do to minimize the effect of wind on the irrigation system is to schedule irrigations during the time of the day when the wind speed is lowest. At Davis and Irvine, CA, the wind speed is lowest before 8:00 A.M.. (Fig. 3).

Crop Canopy. The morphological characteristics of the crop(s) under sprinkler irrigation can lead to the funneling of water toward the container (funnel effect) or deflection of water away from the container (umbrella effect). These two modifiers can have beneficial or adverse consequences depending upon the crop in question and the uniformity characteristics of the irrigation system.

Shade Cloth. Plants growing under shade cloth present problems for sprinkler irrigation. If the sprinklers are placed under the shade, the supporting structure interferes with the application of water. If the sprinklers are placed above the shade to avoid the supports, water distribution patterns will likely be changed.

IRRIGATION SYSTEM CONTROL

"Look and Feel". With experience, one can determine when to irrigate based on how the crop looks and how the soil feels (dry or not). This is probably the best way of determining when to irrigate; however, it is extremely time consuming and labor intensive and certainly not the choice for large-scale production.

Time. Most irrigation is done based on time regardless of the particular crop's need for water. This is easily done with the use of timers controlling irrigation valves. Observant irrigation managers periodically change irrigation timing to reflect

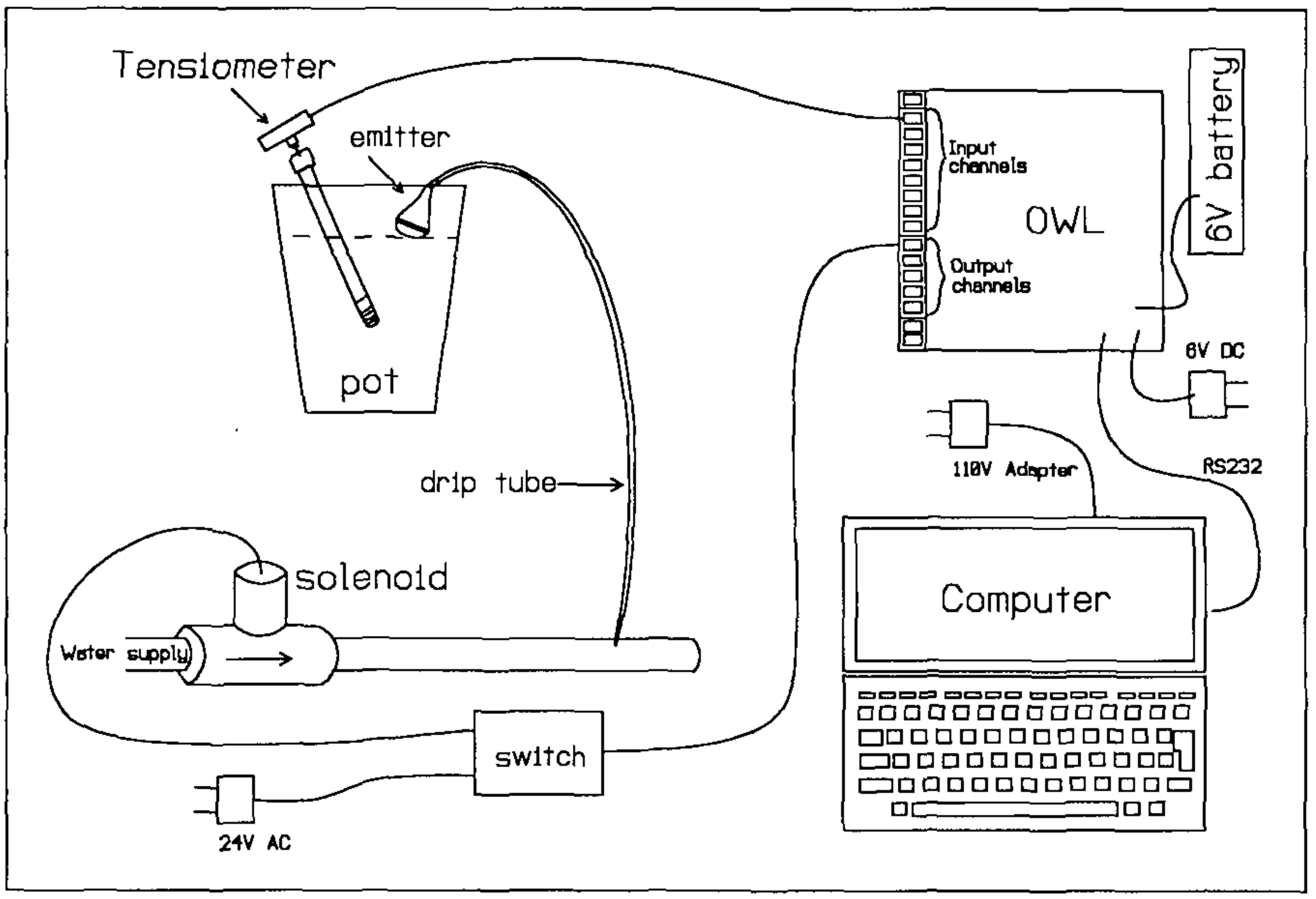

Figure 4. Schematic diagram of UCD-EH, computer-controlled irrigation system driven by a soil moisture sensor (tensiometer).

changes in climate or season. Success with this technique can be largely attributed to the fact that container media are porous allowing overwatering without adverse accumulation of water in the container.

Soil Moisture Sensors. Tensiometers and gypsum blocks that monitor soil moisture characteristics have been used to determine irrigation scheduling. Problems including lack of precision and high maintenance have plagued these devices. The recent development of solid-state tensiometers (Burger and Paul, 1986) for the computer control of irrigation systems in greenhouses (Lieth and Burger, 1988; Fig. 4) may provide solutions to some of the problems while leading to increased water use efficiencies and decreased off-site pollution from run-off.

Solar Radiation Sensors. Solar radiation sensors can be used to control the application of water. An example of this is the solar controllers used to control the flow of water to mist nozzles on propagation benches. These sensors can collect solar radiation, convert it into electricity, determine when to activate the valve, and supply the necessary voltage to the valve. One sensor (Jeffery Electronic Control, Australia) that has been studied at UCD has proven to be successful in controlling the mist benches. During the day, as the incident solar radiation increases, the frequency of water application increases while at night the valve is not activated (Fig. 5). Plants have rooted as well or better under this control system and the water usage has been reduced by one-half.

Stem Water Flow Gauges. A device designed to directly measure the flow of water through stems 1-15 cm in diameter has recently been developed (Baker and

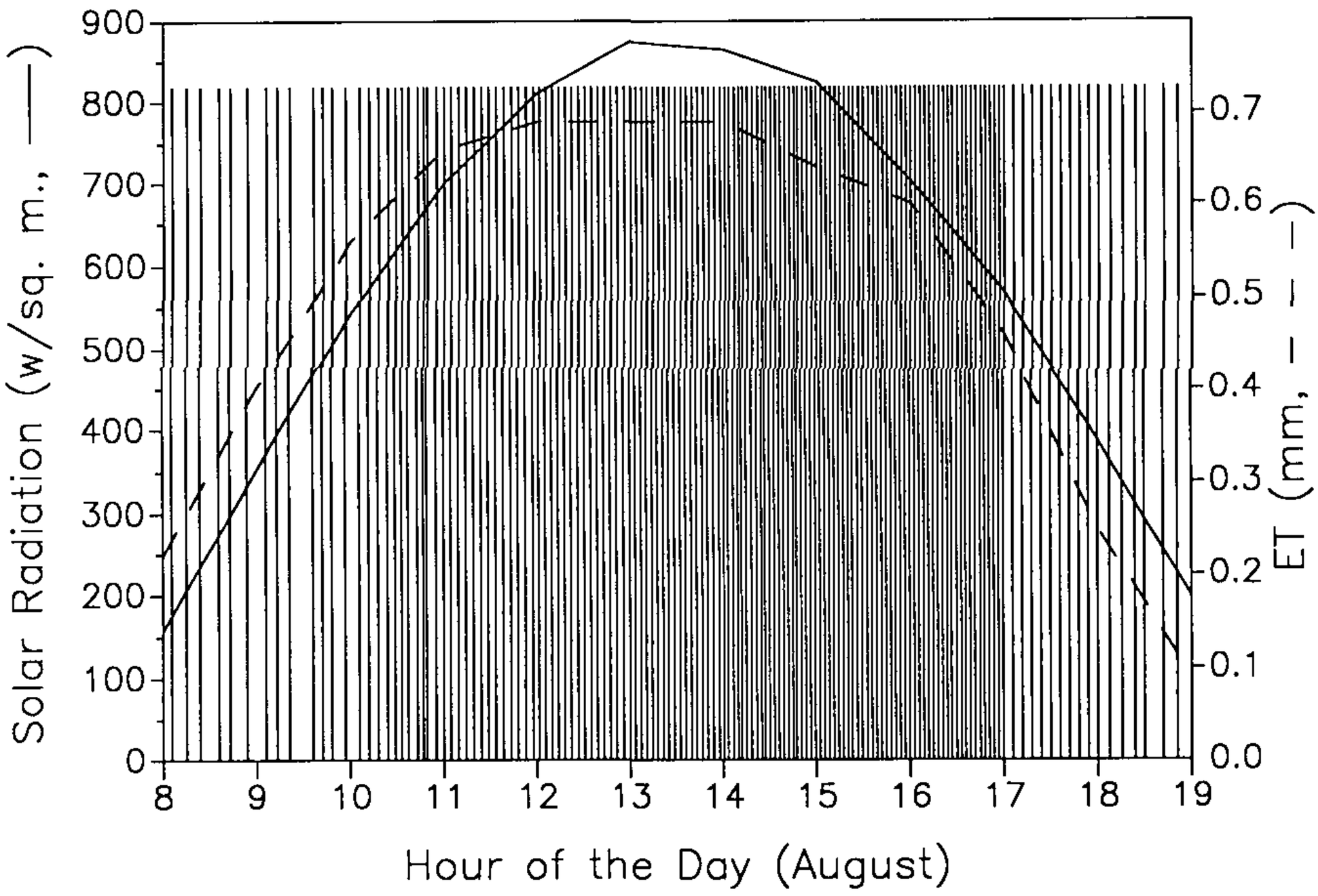

Figure 5. Response of an overhead mist valve (vertical lines) controlled by a solar radiation sensor.

Van Bavel, 1987). The Dynamax Dynagage Stem Flow Gauge (Dynamax Inc., Houston, TX; Fig. 6) may prove to be useful in the measurement of water use for container-grown as well as for landscape plants. At present, it is costly and requires the use of computer interfaces to operate effectively.

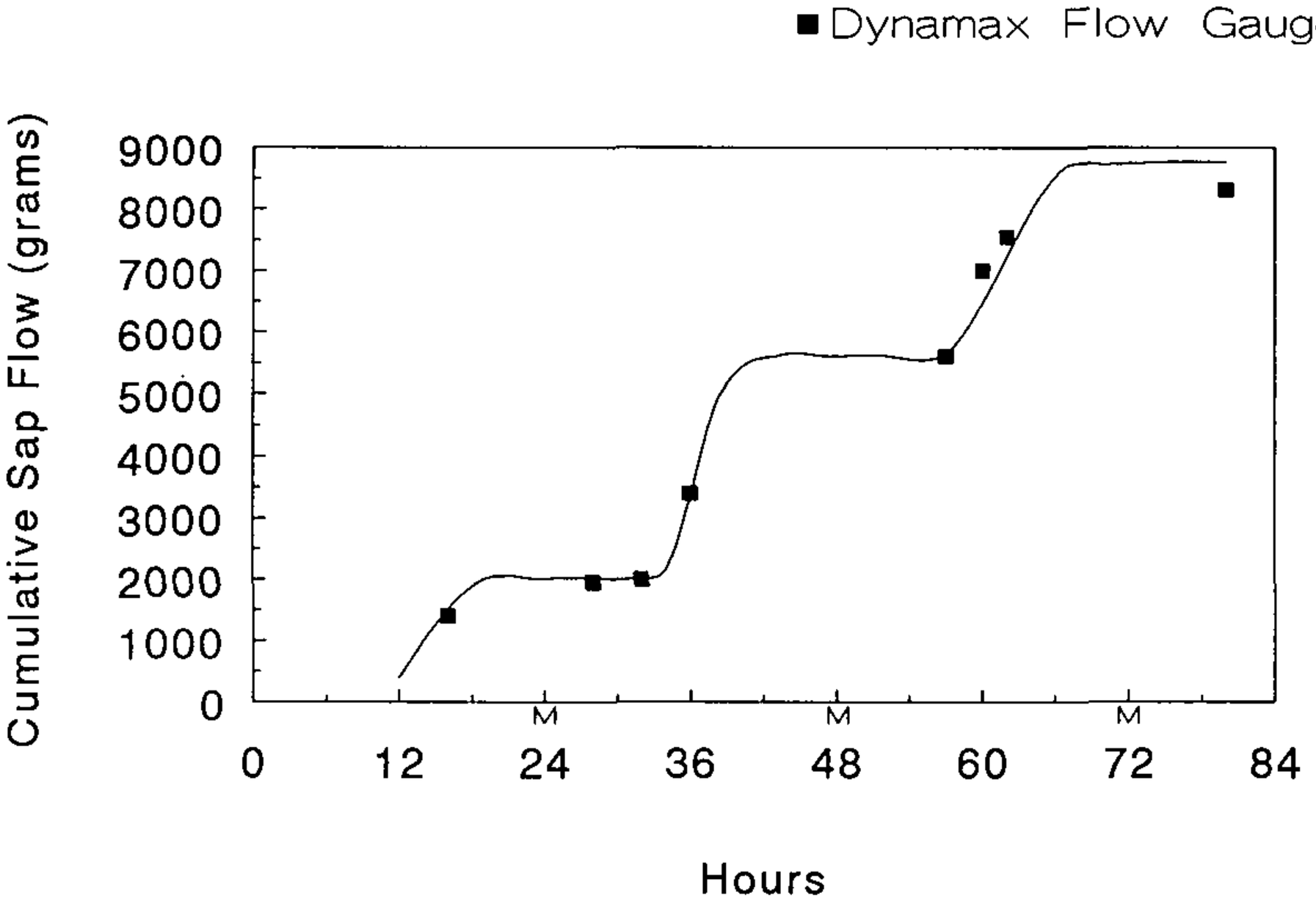

Figure 6. Measurement of water (sap) flow through a plant stem with the use of a Dynamax Flow Gauge. "M" along the X-axis denotes midnight.

Weighing Lysimeters. Research is underway at Davis to determine whether weighing lysimeters can function as irrigation control devices. The advantage of using a weighing lysimeter is that it can weigh several containers and therefore obtain a representative estimation of the water needs of the crop. In practice, the weighing lysimeter would be placed in the nursery bed in the area receiving the least amount of water from the irrigation system and/or in the area with the highest evapotranspiration potential (the south-west corner of the bed). The lysimeter would then dictate when water was applied to the plants it represented.

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Plant Variety Rights and Plant Production—Help or Hindrance?

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INTRODUCTION AND BENEFITS

A plant variety right (PVR) is an intellectual property right. It is available to the breeder of a new plant variety and gives such a breeder the following rights or powers:

- The exclusive right to sell reproductive material or whole plants of the variety and collect royalties on the sales.
- The exclusive right to propagate the variety for sale. This enables the breeder to control the quality of the reproductive material or plants and assists in the orderly marketing of the variety.
- The exclusive right to propagate the variety for the purpose of the commercial production of fruit or flowers. This means that orchard ists and cut-flower growers who wish to propagate new plants of a protected variety themselves, can only do so with the permission of the variety owner. In most cases permission will be given provided royalties are paid.

Where breeders of protected varieties have these exclusive rights they can, if they choose, licence others to do various things. The licensing of propagators and nurserymen reduces the risks involved in commercialisation and is a mechanism that enables control over propagation and a better return on that investment and effort in breeding.

A protected variety may be a valuable saleable asset. The PVR document, by clearly establishing that the breeder is the legal owner of the variety, may assist the breeder in obtaining the best price should he or she wish to sell the variety on its own or as part of a business.

In the various ways indicated PVR provides breeders the opportunity they would not otherwise have to profit from their breeding activities. In the absence of legal protection afforded by PVR, new varieties could easily fall into the hands of others who could carry out pirate propagation and reap rewards that rightly should go to the breeder. By assisting breeders to recover their breeding costs and earn a profit, PVR provides an incentive for investment and effort in the breeding and selection of new improved plant varieties.

PVR also provides an incentive for the introduction and release of improved new varieties from overseas. This effect is particularly evident when a country first implements a PVR scheme. It was noticed in both New Zealand and Australia that North American and European varieties that were previously unavailable, suddenly became available. Many overseas breeders would not allow their varieties to be propagated in New Zealand if PVR were not available here. Plant variety protection has added to the range of plant material available and plant propagators

now have access to overseas varieties that would probably be denied them without a PVR scheme.

OBTAINING AND HOLDING RIGHTS

PVR is available for varieties of any kind of plant. The term variety is used in the sense of a cultivated variety or cultivar—not a botanical variety. To be eligible for PVR a variety must be new, have an acceptable denomination, be distinct from all known varieties, and be uniform and stable (PVR Office, 1990). Distinctness, uniformity, and stability of a candidate variety are determined in a field trial where the candidate variety is botanically described and compared if necessary with similar varieties. The results of the evaluation are often refereed by a designated independent expert. The horticultural or commercial merit of the variety is irrelevant to PVR and not taken into account.

Variety protection does not only affect owners of varieties. PVR has an impact on the plant production system generally. With respect to protected varieties, plant propagators are restricted in some of their activities, e.g. they cannot carry out commercial propagation without a licence, contract, or consent from the variety owner. Plant propagators used to the complete freedom to propagate unprotected varieties may be unhappy when they first face the restrictions applied to protected varieties. However they must accept these restrictions if they wish to have an involvement with improved protected varieties.

At the present time there are some 600 fruit and ornamental varieties that are fully protected under a grant of PVR or provisionally protected, i.e. an application has been made but a decision not yet reached. Of the total number of protected varieties, roses comprise over a third. There are also many varieties of deciduous fruit and cut-flower crops such as carnation and alstroemeria. A recent development has been the protection of a large number of impatiens varieties. The number of other categories of protected ornamental varieties is comparatively low but does show growth.

If a protected variety is propagated without the owner's consent then those doing so risk legal prosecution by the owner and may be liable for payment of damages to the owner. It is up to variety owners, not the PVR Office, to oversee a variety's production. It is not the role of the PVR Office to become involved in infringement problems and disputes concerning non-payment of royalties. A variety owner should in his or her own interest let it be known that the variety is protected. It is up to the owner to determine and collect royalties. The owner can do this on an individual basis or through an organisation for central royalty collection.

Plant propagators should make efforts to keep themselves informed and updated on variety protection matters to ensure they do not infringe the rights of variety owners. There does seem to be some lack of knowledge as to which varieties are protected. A paper on plant variety rights given in the United Kingdom mentioned problems of lack of awareness and understanding of PVR (Costin, 1990). In this country information is available in the quarterly Plant Variety Rights Journal. A full list of fully protected varieties is included in each January issue and a list of provisionally protected varieties in each July issue. More general information is contained in the handbook 'Guide to Plant Variety Rights'.

SOME WIDER EFFECTS

PVR has implications beyond plant propagation and nursery production. It affects all horticultural producers and those who wholesale or retail plants. Protected varieties must be labelled, listed, and advertised with the correct PVR denomination. This is required under the Plant Variety Rights Act 1987 (New Zealand Government, 1987). False claims of protection or failure to use the PVR denominations can result in prosecution and a fine up to $1,000. The PVR Office has recently brought this to the attention of several rose nurseries following denomination errors in their catalogues. A variety can have a commercial name in addition to the PVR denomination. This is very common for rose varieties. In such cases, while it is quite acceptable to label, sell, and advertise protected varieties under the commercial name, the PVR denomination must always be used as well. Variety owners would have difficulty enforcing their rights if they had not been using the correct denomination.

As well as PVR denominations and commercial names, trademarks are sometimes used when varieties are sold. It is important not to confuse PVR protection with trademark protection. A trademark in itself gives no protection to the variety. A trademark is correctly used to apply to the products produced by a particular enterprise. For example, a nursery might register a trademark and apply it to all the plants produced from that nursery. A trademark should not be used as a varietal denomination—indeed it is a condition of trademark registration that this not be done. A person who does use a trademark as a varietal denomination would invalidate that trademark.

COSTS, EXPORTS, AND CONCLUSION

Plant breeding and importing are expensive and involve a long term commitment. Comment is sometimes made about the cost of variety protection. The cost of protecting a variety could be looked at this way. Individuals and businesses routinely pay insurance premiums to protect themselves and their belongings from a variety of disasters. PVR could be looked upon as a form of insurance that protects the investment in a new variety. The total cost of importing and commercially releasing a variety could well be many thousands of dollars. The cost of PVR protection as part of the overall investment is comparatively small. Breeding a new variety can also involve high cost especially if inputs such as time and labour were properly taken into account. The cost of PVR protection as part of total breeding costs would again be comparatively small. Some may argue that selectors of sports or chance seedlings are just lucky and less deserving. However, the successful identification, recognition, and development of a new variety derived in this way depends upon certain skills and requires investment. It seems only fair that the skills of all breeders, selectors, and importers should be rewarded.

The holding of rights in New Zealand may assist in obtaining rights for the new variety overseas where the variety is exported. A New Zealand right is only valid in this country but protection in other countries may be easier to obtain if the variety has a New Zealand PVR. Overseas PVR authorities may accept PVR testing, and the resulting report, carried out in this country. There is a formal New Zealand-United Kingdom cooperative agreement under which, should application for PVR be made in the United Kingdom for varieties of many New Zealand indigenous plant taxa, the New Zealand PVR Office will carry out the PVR testing

for the U.K. PVR Office (New Zealand PVR Office, 1992).

PVR provides justice to breeders, selectors, and importers by enabling them to obtain some financial reward for their effort involved in commercially introducing their variety. This is achieved by allowing the owner of the new variety control of the variety's propagation, production, and release. Variety protection gives some orderliness to the production and marketing of plants. The incidence of pirate propagation is less likely. The marketing of protected varieties is aided by the requirements of labelling and some benefits are passed on to the consumers of plants. The scheme encourages investment in breeding and selection activities and allows New Zealanders access to overseas varieties which may not be available here without the protection that PVR provides. The combined effects of increased breeding and importing give growers, nurserymen, and home gardeners access to a greater range and number of improved varieties. PVR is a help, and not a hindrance to planned commercial plant production.

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Indexing for Dasheen Mosaic Virus in *Zantedeschia* Species

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INTRODUCTION

Over the past few years we have become increasingly aware of virus infection in summer flowering *Zantedeschia* hybrids in New Zealand. The only virus that has been positively identified in commercial crops is dasheen mosaic virus (DMV), a potyvirus that is widespread in aroids around the world. Although it has been possible to eliminate this virus from selected clonal material using meristem-tip culture (Cohen, unpublished data), indexing for the presence of DMV has been difficult because of low virus titre and uneven distribution in the plant.

This paper will describe some of the characters used to classify and name plant viruses, outline some of the methods used to detect (index) and identify viruses, review the literature on viruses reported to infect *Zantedeschia* species, and conclude with some comments on the production and maintenance of *Zantedeschia* cultivars free of DMV.

PLANT VIRUS NAMES

Growers are often confused by the names that are given to viruses and, in particular, to virus group names such as potyvirus or potexvirus. Viruses are classified using a number of characteristics including:

- The shape and size of the virus particle
- The type and number of strands of nucleic acid in the virus particle (RNA or DNA)
- The mode of transmission, i.e. egg, by aphids, thrips, sap, etc.
- The host range of the virus.

On the basis of these characteristics, plant viruses are placed in one of more than 20 groups. Knowledge of these groups tells us about many of the properties to anticipate when we begin to research new virus—plant combinations. For example, DMV is a potyvirus and it belongs to a large group of viruses infecting many important crop and ornamental species. This group includes potato virus Y, bean yellow mosaic virus, iris severe mosaic virus, narcissus yellow stripe virus, and tulip breaking virus. Viruses in this group have rod-shaped particles about 750 nm long, they usually have a narrow host range, and they are usually transmitted by aphids in, what is called, a non-persistent manner. This means that aphids probing the crop with its mouth parts can acquire the virus within minutes or even seconds and then transmit it to a new plant, but the virus does not persist on the aphid for more than a few hours. This information is very helpful in devising ways to reduce virus spread.

VIRUS INDEXING

Viruses are usually first detected on plants by the presence of symptoms, but symptomless infection may occur in some hosts and/or at some times of the year. To index for the presence of virus, we employ a variety of methods such as transfer of the virus to indicator plants, i.e. plants which produce characteristic symptoms following infection. We usually rub plant sap onto the surface of a young leaf on the indicator plant and wait for symptoms to appear one or two weeks later. In some cases we use aphids to transfer the virus, or diseased tissue is grafted onto a healthy indicator plant. The electron microscope (EM) can be used to detect viruses in plant sap and this is a very useful method for rod-shaped viruses. Different groups of viruses have different shapes of particles, but we cannot usually distinguish between viruses within a group, such as the potyviruses, using the EM alone. A variety of serological methods are available but the ELISA procedure is the most widely used for diagnostic purposes. Kits for detection of many plant viruses are now available commercially. Some of these kits will only detect specific strains of a virus, but in one case a kit is claimed to detect all the aphid-spread viruses in the potyvirus group (Jordan and Hammond, 1991). Another serological technique that has recently been described is the 'squash blot' (Lin et al., 1990). In this procedure cut plant surfaces are pressed against a nitrocellulose or nylon membrane. The presence of virus is then detected using enzyme-labelled antiserum followed by a reagent that gives a colour reaction in the presence of the virus/antiserum/enzyme complex. A number of molecular procedures are also available, some of which can detect extremely low levels of virus (Langefeld et al., 1991).

The ability to detect a virus depends on the sensitivity of the assay used, the titre (concentration) of the virus in the plant tissues, and the distribution of the virus in the plant tissues. Where virus titre is high and where the virus is evenly distributed in the plant, detecting the virus is usually simple and reliable. However, when virus titre is low and/or there is uneven distribution, it is very easy to miss the presence of virus (i.e. false negatives). For this reason we try to find ways of raising virus titre and to understand the factors affecting virus distribution in order to improve index reliability (Cohen et al., 1986).

VIRUSES IN *ZANTEDESCHIA*

DMV is widespread in a number of aroid plants including *Zantedeschia* (callas) in many countries (Table 1). It has been reported on *Z. aethiopica*, *Z. elliottiana,* and other species from U.S.A. (Zettler et al., 1970), South Africa (Van der Meer, 1985), and Italy (Rana et al., 1983). In New Zealand, it has been detected in many summer flowering *Zantedeschia* hybrids (Balasingam, pers. comm.; Cohen, unpublished data), but has not been detected on *Z. aethiopica*. DMV is a potyvirus and is transmitted by aphids. It has rod-shaped virus particles, which can be easily recognised using an electron microscope.

Tomato spotted wilt virus (TSWV) was the first virus to be detected on callas (Tompkins and Severin, 1950). Chamberlain (1954) reported the presence of TSWV in *Zantedeschia* in New Zealand. In Europe, it is possible that mosaic symptoms attributed to TSWV may, in some cases, have been caused by DMV (Kolbasina and Protsenko, 1973).

A number of other viruses have been reported to infect callas. Both Salinger (1985) and the new Royal Horticultural Society 'Dictionary of Gardening' report

that callas are infected by CMV but no references were cited. Chamberlain (1954) reported CMV on *Zantedeschia* species in New Zealand and Fletcher (1987) detected CMV in a sample of *Z. albomaculata* from a garden in Christchurch, New Zealand.

Arabis mosaic virus (AMV) and potato virus X (PVX) have been reported on *Z. aethiopica* in Poland and Japan respectively (Okuyama and Saka, 1976; Kaminska, 1985), and tobacco mosaic virus (TMV) has been found on *Zantedeschia* spp. in South Africa (Gorter, 1981), but it is unclear whether these infections are widespread even in these countries.

Table 1. Viruses that have been reported to infect *Zantedeschia* species.

Virus	Shape	Host range	Vector	Reference
Dasheen mosaic virus (DMV)	rod-shaped	aroids	aphids	Zettler et al. (1970) Rana et al. (1983) Kolbasina and Protsenko (1973) Van der Meer (1985)
Cucumber mosaic virus (CMV)	spherical	wide	aphids	Chamberlain (1954) Fletcher (1987)
Tomato spotted wilt virus (TSWV)	spherical	wide	thrips	Tompkins and Severin (1950) Chamberlain (1954)
Potato virus X (PVX)	rod-shaped	wide	non insect	Okuyama and Saka (1976)
Arabis mosaic virus (AMV)	spherical	wide	aphids	Kaminska (1985)
Tobacco mosaic virus (TMV)	rod-shaped	wide	non insect	Gorter (1981)

It appears that DMV is the major viral disease of hybrid *Zantedeschia* in New Zealand, but there have been no experiments to quantify the effects of DMV infection on tuber or flower production. Nor have there been any studies on the effects of other factors on the severity of infection. However, comparison of the growth of micropropagated plants of several cultivars that had been freed of DMV with the growth of the original stock showed enhanced vigour and delayed senescence. Plants with severe mosaic symptoms on leaves, often show streaks and/or spots on the spathe of the inflorescence. I have found that these symptoms are associated with zones of higher virus titre.

This raises the issue of the distribution of virus within the plant. The assay for DMV employed in this laboratory uses the broad spectrum potyvirus monoclonal antibody produced by Jordan and Hammond (1991) and commercially available from Agdia Inc. (Elkhart, Indiana, U.S.A.). This assay procedure has been found to be sensitive and reproducible for replicates taken from the same leaf. A sample

size of 20 to 50 mg is collected and this is ground in 2.0 to 5.0 ml of the recommended extraction buffer. This represents a 1/100 dilution of the plant tissue. The sample can be further diluted to determine the titre of the virus in the tissue. For a leaf sample with severe mosaic symptoms, positive reactions can be obtained when the tissue is diluted down to 1/7000. In contrast, for tuber samples from the same plants, virus has only been detected in samples diluted to 1/800. DMV was often undetectable from other samples taken from the same tuber.

The squash blot technique has been used to detect DMV in tuber sections (Lin et al., 1990). Sections were cut longitudinally through the tuber and pressed on to a nitrocellulose membrane. The virus was detected after soaking the membrane in the Agdia potyvirus antiserum followed by a detection reagent. Zones with high titre were clearly seen in the basal part of the tuber. Virus was either not detected or was present at much lower titre in the upper and central parts of the same tuber.

Further evidence for uneven virus distribution can also be seen from the expression of virus symptoms. Sometimes virus symptoms on different shoots on the same tuber or even different leaves on the same shoots will vary from symptomless to severe. The titre of virus in leaf tissues seems to closely reflect the symptoms observed. This result suggests that leaves might be susceptible to infection only at an early stage of leaf development.

To distinguish between samples which are free of DMV and samples with a very low virus titre, it will be necessary either to develop a more sensitive assay system or to learn how to raise virus titre. It may be possible to raise the titre of the virus in leaves by defining a temperature range which promotes virus replication in the tissues and growing the plants within this temperature range. This approach would be particularly useful when we are trying to index for virus following meristem-tip culture. If we can reliably index shoots in vitro, virus-free shoots could be micropropagated immediately, saving considerable time. This approach worked very well with lilies (Cohen et al., 1985; Cohen, 1986), but we do not yet know whether this approach will work for *Zantedeschia* hybrids.

PRODUCTION AND MAINTENANCE OF PLANTS FREE OF DMV

What are the best ways to obtain and maintain plants free of DMV? Although we can now use the ELISA method to determine whether leaves with mosaic symptoms or narrowed leaves are infected with DMV, there is currently no simple way to determine the percentage infection in a block of plants. To be certain that a plant is free of DMV, the plant should be indexed several times over preferably two growing seasons. If infected tubers are used as mother stock for micropropagation at least some of the resulting tubers will be infected. For this reason, only virus-free tubers should be used to initiate cultures for micropropagation. As mentioned above, it is possible to produce virus-free plants using meristem-tip culture and this is recommended if an alternate source of virus-free plants of the cultivar is not available.

To reduce the risk of reinfection, micropropagated plants from DMV-free cultures, should not be grown with non-indexed stock. In addition, virus-free tubers should preferably be stored separately from infected stock, particularly when the new sprouts are beginning to emerge. Aphid infection at this stage might transmit virus.

CONCLUSION

Techniques for detecting DMV in *Zantedeschia* have been improved. When combined with the use of meristem tip culture, it is possible to produce plants free of DMV. Precautions need to be taken to prevent reinfection.

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A Critical Analysis of the Status of Rose Wilt Virus

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INTRODUCTION

Since Grieve (1931) published his paper on "Rose Wilt" and "Dieback" there has been an increasing range of symptoms attributed to rose wilt virus (RWV) based on no other evidence than supposed visual similarities. Reports of occurrence have been based on observation of one or more of these various attributed symptoms. There has not been any definitive work done either on the characterisation of a viral pathogen or on whether the symptoms subsequently attributed to the disease bear any relationship to those described by Grieve. There is currently no adequate characterisation of either a virus causing a wilt of roses or of the symptoms initiated by such a causal agent. This paper surveys the literature and research on RWV and examines the hypothesis that no such virus exists.

DISCUSSION

A wilt and dieback of roses was first described by Brundrett (1929) in the Australian Rose Annual. Grieve (1931) attributed this disease to a virus. In 1931 knowledge of viruses was very limited and in general any agent which caused symptoms after being passed through a filter which removed bacteria and fungi was deemed to be a virus. In this context Grieve's assumption that the causal agent was a virus was quite appropriate at that time. It is significant that no one has subsequently infected roses with a virus which has reproduced the symptoms described by Grieve.

As was pointed out by Dimock (1951) the symptoms of RWV as described by Grieve (1931; 1933; 1942) were virtually indistinguishable from the symptoms of *Verticillium* wilt. A close examination of Grieve's (1931; 1942) description of symptoms shows that these are indistinguishable from those of *Verticillium* wilt (personal observation). In particular the characteristic translucent yellowish-green appearance of the young dying stem and the area around the buds remaining green even after the stem has become brown.

It should be noted from illustrations and descriptions in Grieve's papers that the symptoms he describes are a wilting and dieback of young shoots with a recurving of leaflets about the rachis. This bears no resemblance to the rosetting on mature plants and loss of apical dominance and proliferation of maiden plants attributed to RWV by Stubbs (1968) when he visited New Zealand which was subsequently described as RWV by Fry and Hammett (1971). There has been no experimental evidence linking these symptoms or relating them with those described by Grieve. They must therefore be considered to be of distinct etiologies.

The method used by Grieve was one of extracting sap from diseased plants, separating it from fungal and bacterial pathogens, introducing it into healthy plants, and reproducing part at least of the original syndrome. This is almost exactly that subsequently proposed by Dimond and Waggoner (1953) as proof of a "vivotoxin" being involved in symptom expression in the case of fungal or bacterial diseases.

Verticillium not only produces low molecular weight toxins (Talboys, 1957) but also cellulolytic and pectic enzymes. Although Grieve's assumption that the *Verticillium*-like symptoms that he was transmitting were caused by a virus was appropriate at the time, we must, in the light of present knowledge, accept that he was in fact causing symptoms in healthy plants by introducing *Verticillium* toxin into them. No one has subsequently shown these symptoms to be caused by a virus.

Various anonymous reports from the New South Wales Department of Agriculture (1953; 1958; 1962; 1969) described the occurrence of RWV in Australia. However, these reports attributed to it a much wider range of symptoms than those described by Grieve. On the basis of observation of some of these symptoms, similar diseases were reported in Italy (Gigante, 1936), in Czechoslovakia (Klastersky, 1949; 1951), in New Zealand (Stubbs, 1968), in South Africa (Meyer, 1960) in the U.S.A. (Cheo, 1970; Slack et al., 1976b), and in the U.K. (Ikin, 1971).

Following Stubbs' visit to New Zealand, Fry and Hammett (1971) investigated the symptoms which were then considered to be caused by RWV. The symptoms described by them fall into two separate syndromes. Those on maiden nursery plants occur in spring when initial growth from the scion bud produces multiple tapered shoots with grossly reduced leaves but normal sized stipules. This condition has been termed "proliferation" (Gardner, 1970). The symptoms on mature plants are characterised by general debility, rosettes of leaves from lateral buds on previous season's wood, and dieback of old wood. This describes the symptoms on the plants that were grown at the Department of Scientific and Industrial Research (DSIR) as a source of infected material for graft transmission experiments (Gardner, personal observation).

The rosetting symptom is a true rosette of leaves, i.e. that is a number of small circularly arranged leaves arising from the one point without any internodal elongation and occurring from lateral buds on the previous season's canes. Fry and Hammett (1971) are quite wrong in equating this symptom with the balling of leaves by recurving of the leaflets on young growth as described by Grieve. This is further confused by Figure 4 in their paper which shows balling of leaves on young shoots of 'Queen Elizabeth' which is not at all typical of the rosetting symptom characteristic of their infected material.

They found that inoculum from 'Queen Elizabeth' with epinastic balling rather than rosetting, failed to produce symptoms on a range of herbaceous hosts. Inoculum from plants with the rosetting symptom consistently produced local lesions followed by systemic mottle and line pattern on *Chenopodium amaranticolor*, *C. quinoa* and *Cucumis sativus* (Gardner, 1983).

Virus purified from cucumber infected with sap from rosetted roses proved to be *Prunus* necrotic ringspot virus (PNRSV) and reacted homologously with PNRSV-RA antiserum from Fulton (Fulton, 1968; Gardner, 1983). Plants with the rosetting symptom grown at DSIR for graft transmission experiments were tested serologically using the enzyme-linked immunosorbent assay (ELISA) technique and were found to be positive for PNRSV (Gardner, 1983).

This would suggest that the virus transmission experiments by double budding (Fry and Hammett, 1971) were in fact transmission of PNRSV. The symptom transmitted to the 'Super Star' indicator was an initial epinasty or down curling of the shoot from the bud and did not in any way resemble the proliferation symptom (Gardner, personal observation).

The proliferation symptom on young maiden plants is invariably associated with more or less excessive callus and galling occurring primarily at or below ground level, and, secondarily, at the bud grafting wound and point of excision of the stock top (Gardner, 1972). Proliferation in New Zealand is initially caused by wounding, commonly by hoe weeding in the spring prior to budding. This results in gall formation at the wound and secondary gall initiation subsequently at the budding incision. Gall and callus growth behind the bud becomes active when the bud is forced into growth in spring, twelve months after the initial infection. This unorganised tissue interrupts the vascular connection between the shoot and the understock and probably also results in a hormonal imbalance. (Gardner, 1972 and unpublished results).

Attempts to isolate pathogenic bacteria, in particular *Agrobacterium* have been unsuccessful (Fry and Hammett, 1971; Gardner, 1972; Bos and Perquin, 1975). However, this is not surprising because as little as 72 hours is needed for *A. tumefaciens* to initiate tumor formation and it is often hard or impossible to isolate that pathogen from abnormal tissue (Klement, 1974).

In other plants, shoots arising from crown gall tissue frequently produce teratomatous organoid witch's broom-like structures similar to proliferation in roses (Dye, 1959). Apart from attempts to isolate bacteria from excess callus, Fry and Hammett (1971) showed that excess callus was not associated with their virus infection. They did, however, state that "... the possibility should not be overlooked that factors producing such excess callus might also influence the number of shoots formed by an infected bud."

Rose bud proliferation in the Netherlands was examined by Bos and Perquin (1975). These authors came to a similar conclusion to that of Gardner (1972), viz. that symptoms were caused by a hormonal imbalance brought about by wounding at budding and a pathogenic microorganism disappearing after the onset of the pathological process. A similar condition has been described as rose stunt or dieback in England.

A failure to obtain graft transmission of the proliferation symptom (Hutton, 1970; Gardner, 1972; Ikin and Frost, 1974; Bos and Perquin, 1975; Thomas, 1980; Gardner, 1980) would indicate that this is not caused by a virus.

There are a considerable number of references which have not been dealt with herein. Most of them are based on observation of symptoms with failure either to identify a causal agent or to transmit the disease. There are, however, a number of papers which warrant further comment.

Hammett (1971) makes a comparison of symptom differences between rose wilt virus as he interprets them and *Verticillium* wilt. The symptoms he attributes to RWV cover the balling of leaves on young shoots as described by Grieve, the rosettes of leaves arising from lateral buds on previous season's canes, and dieback of old wood. No obvious mention is made of the proliferation symptom. It is interesting to note that no mention is made of the characteristic yellowing and browning of the internodes of young canes with green islets remaining at the nodes. This characteristic is a major feature of Grieve's description of RWV symptoms and is also a very characteristic symptom of *Verticillium* wilt in roses.

The observations by Marcussen (1974) attributed to RWV relate to plants showing symptoms indistinguishable from *Verticillium* wilt and the spread of the disease is typical of a soil-borne fungal pathogen. Slack et al. (1976a;b) describe two

virus-like diseases in California. Both these diseases have some features in common with some of the symptoms attributed to RWV by Fry and Hammett. The rose leaf curl (RLC) paper illustrates a maiden plant with typical proliferation symptoms. However, the authors state that this symptom on its own should not be considered diagnostic for RLC in nursery plants as it may be caused by other factors.

CONCLUSION

There are at least three and almost certainly more distinct diseases which have been attributed to RWV. A distinct RWV has not been characterised or shown to cause any one or more of those diseases. Alternative causal agents can be considered to produce each of the various syndromes attributed to RWV.

Verticillium dahliae can cause the symptoms originally described by Grieve. The symptoms in mature plants of rosettes of leaves and dieback of mature canes is a syndrome which can occur with infection by PNRSV. The proliferation syndrome in maiden plants cannot be shown to be viral. In New Zealand it generally occurs in association with crown gall type callus. Similar symptoms may have different causal agents which produce abnormal growth in other instances and in other countries.

Rose wilt virus has no definitive symptoms nor has a distinctive viral pathogen been transmitted or characterised. It is concluded therefore that it must be regarded as a *nomen nudum* and reports of it should be regarded as referring to one or more of the various unrelated syndromes which have in the past been attributed to it.

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The New Zealand Citrus Budwood Scheme

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A scheme to supply New Zealand citrus propagators with superior, virus indexed budwood is being established. Superior clones of major citrus cultivars are being selected in orchards and will be indexed for citrus tristeza virus (CTV) and citrus viroids. These trees will provide budwood for the next 5 to 6 years. Budwood supply blocks have been planted with indexed cultivars, and will supply all budwood when mature. Imported CTV free cultivars are now maintained in an aphid-proof glasshouse until suitable mild strains of CTV can be found for preimmunization.

INTRODUCTION

Traditionally the New Zealand citrus industry has been a relatively small horticultural sector, supplying some 20 to 30 thousand tonnes of fruit to the domestic market; exports have been erratic and account for only a small percentage of annual production. During the past decade, however, a significant change in attitude has occurred amongst citrus producers, prompted by initiatives from growers, researchers, and marketers which have aimed to lift the professionalism of the industry and increase the production of export quality fruit.

These initiatives include cultivar and rootstock introduction, breeding of new easy peeling selections, integrated pest management studies, and nutrition and orchard microclimate research. This change in the perceived potential of citrus production in New Zealand has spurred a replanting phase. Large new orchards are now being planted expressly for export production. To ensure that this new wave of plantings is based on the best available plant material, it is essential that only true-to-type, virus-indexed budwood is used during propagation.

To fulfill this requirement, an ambitious project has been started by citrus growers, nurserymen, and researchers which is of great importance to the future of the citrus industry in New Zealand. The New Zealand Citrus Budwood Scheme is a joint venture between the New Zealand Fruitgrowers Federation and the Horticulture & Food Research Institute. This paper describes how a scheme is being established for the supply of superior citrus buds, buds which will later become superior citrus trees.

CITRUS VIRUS AND VIROID PROBLEMS

Citrus suffers from many virus and virus-like diseases, most of which are transmitted in budwood. If a budwood supply tree is infected, then so are all the trees propagated each year from its buds. Fortunately, New Zealand is free of many of the debilitating virus diseases which occur overseas. However, we do have two areas of concern: citrus tristeza virus (CTV)(Mooney and Harty, 1992) and the citrus viroids, which include citrus exocortis (CEV) (Harty, 1991) and cachexia.

CTV is the most destructive of all the virus and virus-like diseases of citrus, and is widespread in New Zealand orchards. CTV is spread in the field by aphids. The

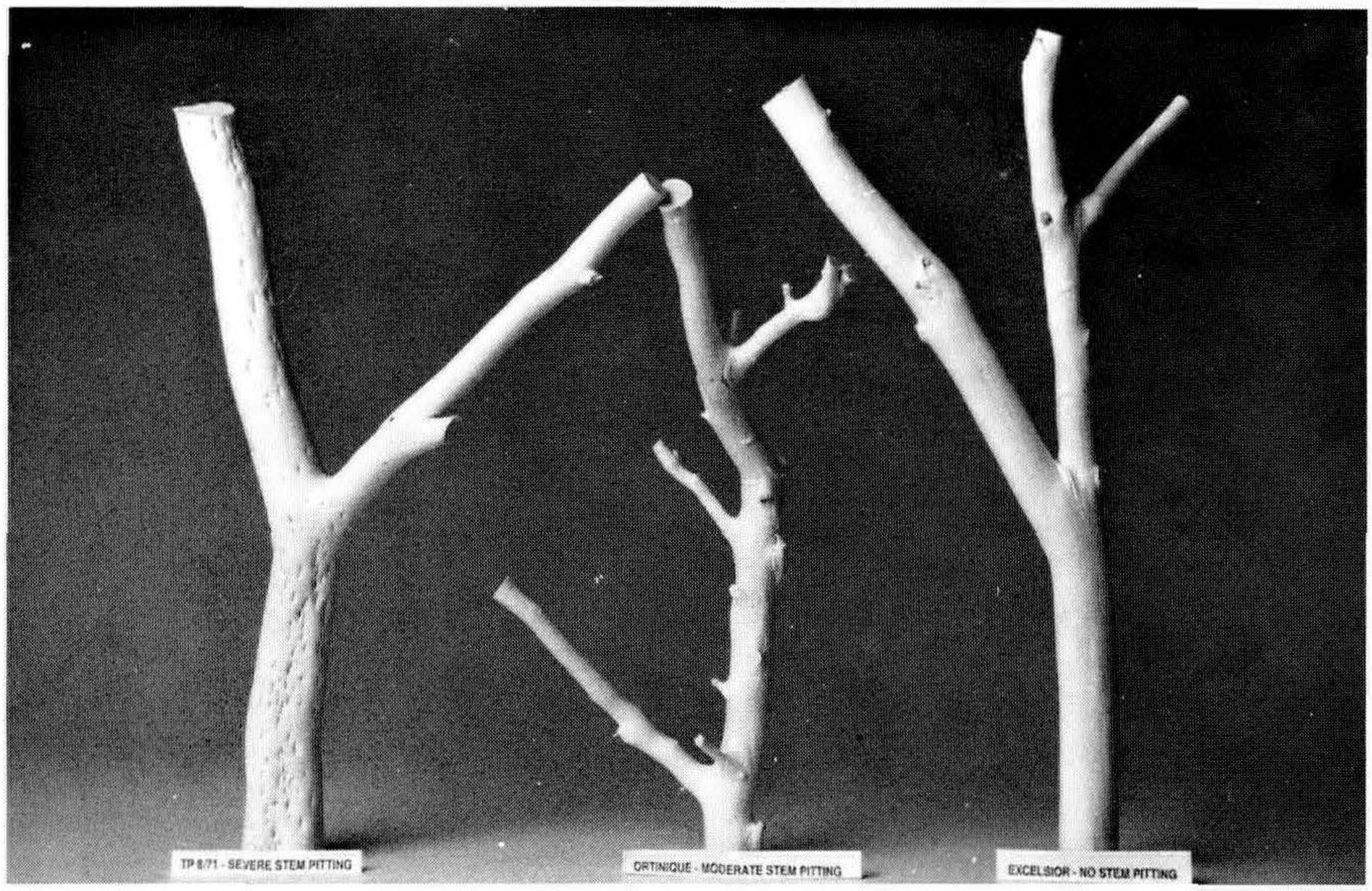

Figure 1. Tristeza stem pitting on wood collected from orchards in Te Puke and Kerikeri.

most efficient vector, the black citrus aphid (*Toxoptera citricida*) is ubiquitous in New Zealand, complicating the control of this disease. Different strains of CTV are known to exist, which may be responsible for symptoms ranging from slow decline, stunting, and, in the extreme case, death of the tree (Bar-Joseph et al., 1981). In a recent survey of the Kerikeri district, stem pitting symptoms were detected in all of the citrus cultivars screened, with symptoms ranging from severe to mild (Fig. 1).

In order to control CTV, we need to be aware of two factors: (1) the need to stringently prevent the introduction of any further tristeza strains, and (2) the need for mild strain protection in the future. Mild strain protection works on the basis that trees inoculated with mild CTV isolates, and later infected with a severe strain, will not express the symptoms of the severe isolate. Increasing use of preimmunized plant material in any region may lead to a change in the composition of the field CTV isolates, resulting in the mild strain predominating. This also has the advantage that a decrease occurs in infection pressure from the severe isolates.

The development of mild strain protection is of particular importance for all new cultivar imports, which are determined free of CTV before their release from quarantine. Local strains of CTV which are not particularly severe in the majority of currently grown citrus cultivars could prove fatal to these new importations. Therefore, until such time as we are able to preimmunize these cultivars with selected mild strains, two trees of each virus free cultivar will be housed in an aphid-proof glasshouse at Kerikeri Research Centre.

Citrus exocortis viroid (Fig. 2) and other citrus viroids (CV) are only spread through infected budwood and on infected cutting tools, e.g. secateurs, clippers, and budding knives. There is no evidence that they are transmitted by insects or in citrus seed, but they can be spread from infected to neighbouring trees within an orchard by root grafting (P. Barkley, pers. comm.). Transmission in nurseries is mainly through use of infected budwood and contaminated budding knives and

Figure 2. Typical exocortis symptoms on trifoliate stock of a young satsuma tree.

digging tools, while in orchards, blades of clippers, secateurs, and implements such as mechanical hedgers can spread the disease. Fortunately, because of the limited ways in which they can be transmitted, the spread of CEV and CV is easily prevented through the use of clean budwood and simple hygiene techniques.

INFERIOR BUDLINE PROBLEMS

Citrus trees have a fairly high rate of natural mutation, and tend to throw "sports" quite commonly. The most obvious of these mutations are sectoral chimeras which can be seen on trees as fruit with ridges, or variegated leaves. Very occasionally, a sport is an improvement on the original parent, but the majority of mutations result in a reduction in quality. If budwood is cut from trees which are not regularly inspected for fruit quality, then there is a high risk of propagating new trees which are derived from inferior sports. Citrus budwood is usually cut when there is no fruit on the tree, so it is very difficult to see whether poor sports are present.

When walking through many New Zealand orchards, it is apparent that many trees have been grown from inferior budwood selections. Yields and pack-out of fruit could be dramatically improved in many orchard blocks at no extra effort other than ensuring that each tree was grown from a superior selected bud.

SOLVING BUDWOOD PROBLEMS

Firstly, the very best clones of each commercial citrus cultivar will be selected in the Kerikeri, Bay of Plenty, and Gisborne districts. This selection process was begun this year, and good progress has been made. Secondly, a glasshouse (Fig. 3) and laboratory at Kerikeri Research Centre have been set up for virus and viroid indexing, and we will begin checking each selected cultivar for viroids and CTV. Biological and biochemical techniques are used in the indexing procedures: Etrog citron and sPAGE for viroids, and Eureka lemon and sweet orange bioassays and ELISA for CTV.

If good viroid-free clones cannot be found for some cultivars, then we will carry out shoot tip grafting on these cultivars to free them of viroids and CTV. A shoot tip grafting laboratory is due to be set up in 1993. All selected cultivars will be shoot tip grafted to free the material of CTV, prior to immunization with mild CTV strains.

For the next 5 to 6 years, budwood will be cut from the selected, indexed trees on orchards. Meanwhile, we have begun planting budwood blocks at Kerikeri Research Centre (Fig. 4). Cultivars which have been imported from overseas, and have been checked for viruses and viroids in quarantine, have already been planted. As the selected cultivars from the districts are certified free of viroids, then they will also be planted in these blocks.

Our intention is to eventually supply budwood of all citrus cultivars through the Budwood Scheme. However, while the Scheme is still in its infancy, we will viroid index cultivars in order of priority, based on numbers of buds required by nurserymen. All new citrus cultivars from overseas introductions will be released through the Budwood Scheme. The Citrus Sector of New Zealand Fruitgrowers Federation has introduced 60 new cultivars during the past four years, and these are now being released from plant quarantine. New selections from the citrus

Figure 3. Etrog citron indicator plants in the insect proof house at Kerikeri Research Centre.

breeding programme will also be released via the Budwood Scheme. Our breeding programme has expanded significantly in the last three years, and we now have 4,500 hybrid seedlings under evaluation. Already one selection, a Clementine mandarin × seminole tangelo hybrid, is being prepared for commercial release.

Figure 4. Viroid free trees in the budwood multiplication blocks at Kerikeri Research Centre.

CONCLUSION

Superior, disease-free propagating material is the foundation stone of all successful plant industries. By starting a budwood scheme, the citrus industry of New Zealand has put into motion a project to ensure that our citrus orchards of the future are based upon the very best available planting material. Although the effort required to establish the scheme is large, the benefits reaped in the future will be correspondingly great.

Acknowledgements. We thank the Citrus Sector of the New Zealand Fruitgrowers Federation and AGMARDT for financial assistance. We would also like to thank Pat Barkley for her invaluable advice and encouragement at each stage of the on-going development of the New Zealand Citrus Budwood Scheme.

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Micropropagation of *Nerium oleander*

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***Nerium oleander* 'Petite Salmon' was successfully established in vitro from shoot tips taken from spring growth. Multiplication was achieved on Murashige and Skoog (MS) medium with 3 mg/l BAP. A prerooting treatment was used with MS medium and either 0.5 or 1.0 mg/l BAP. Rooting occurred on half-strength MS medium with 1 mg/l IBA. Plantlets flowered 7 months after deflasking.**

INTRODUCTION

The bacterium *Pseudomonas savastanoi* attacks the stems, foliage, and inflorescences of *Nerium oleander*. Brown lesions form on the leaves, and the stems blacken and die back. Because of the bacterial infection, it can be difficult to obtain clean plant material for cuttings. Also, the time of the year for taking cuttings is restricted to the summer months (January and February) with rooting occurring in March. Micropropagation is a useful method for the production of stock plants free of disease for the general cutting-grown production plants. In New Zealand, if the plantlets are deflasked in July and August, this tissue culture technique can produce a bushy plant suitable for taking cuttings in November-December.

MATERIALS AND METHODS

Several *N. oleander* 'Petite Salmon' plants, 30 to 40 cm high, were held in containers and sprayed with a fungicide mixture. Shoots 2 to 3 cm in length were cut from the new spring growth. These explants were disinfested with a 3-sec dip in ethyl alcohol, a 20-min wash in 0.6% sodium hypochlorite, and followed by three washes in sterile distilled water.

The basic medium trialed for initiation and shoot multiplication was full strength Murashige and Skoog (MS) minerals with Linsmaier and Skoog vitamins, 30 g/l sucrose, 7 g/l Davis agar with the pH adjusted to 5.5 (Table 1). The cytokinin benzylaminopurine (BAP) was added at 0.1 to 5.0 mg/l. Media were sterilised under pressure at 121°C for 20 min. Plant pieces were subcultured at 4-week intervals and grown in a culture room at a temperature of 25°C, photoperiod of 16 h, and light intensity of 2,000 lux. The medium used for root formation was either liquid or solid half-strength MS medium with 1 mg/l indolebutyric acid (IBA) (Table 1). The growth retardant paclobutrazol at 1 mg/l active ingredient was added to the rooting medium in an attempt to increase the survival rate after deflasking.

RESULTS

After disinfestation the explants grew new axillary shoots. These shoots were cut and subcultured onto a range of media. The most successful medium for shoot production was full strength MS with 3 mg/l BAP. Shoots gave a 3-fold multiplication rate while maintaining a small leaf size which made dissection easier.

Changing the hormone strength to 0.5 or 1 mg/l BAP for 2 weeks encouraged more upright growth and was an excellent prerooting treatment. Roots formed within 2 weeks, when the shoots were transferred to a half strength MS medium with 1 mg/l IBA, or when this rooting medium was added in liquid form at the prerooting stage. When paclobutrazol (1 mg/l) was included in the liquid rooting medium the shoots produced fewer roots which were shorter and thicker. The rooted plantlets were transferred to a 2 peat : 1 bark : 1 pumice sand (by volume) mixture in a humidity tent moistened by a fog system. The survival rate varied between 50% and 70% and was better when deflasking took place in the spring months from Sep.-Nov. The addition of paclobutrazol at 1 mg/l did not alter the rooting percentage in vitro or the survival rate at deflasking. The plantlets grew straight upwards without branching until, after 3 months, axillary bud break occurred and the plants bushed out. This could be accelerated by pinching out the shoot tips. Plants flowered after 7 months although it was better to encourage vegetative growth at this stage.

DISCUSSION

In the U.S.A. *N. oleander* cultivars have been micropropagated for some time at Monrovia Nurseries. At the Arslev Research Station in Denmark this species is micropropagated to produce stock plants for the general cutting-grown production of pot plants. In New Zealand, if the plantlets are deflasked in July and August, this tissue culture technique can produce a bushy plant suitable for taking many cuttings in Nov.-Dec. This will ensure good survival of the rooted cuttings through the following winter and freedom from the troublesome oleander knot.

Table 1. Media recommended for the micropropagation of *Nerium oleander*.

Murashige and Skoog (MS) full-strength mineral medium supplemented as follows:	myo-inositol	100	mg/l
	thiamine HCl	0.4	mg/l
	sucrose	30	g/l
	Davis agar	7	g/l
	pH	5.5	
shoot multiplication:	BAP	3.0	mg/l
prerooting medium:	BAP	0.5 to 1.0	mg/l
root elongation:	MS half-strength mineral medium supplemented as above, with 20 g sucrose and 1.0 mg/l IBA. This medium could be used either solid or in liquid form as an addition to the prerooting medium.		

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Propagation of cherimoya *(Annona cherimola)*

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Satisfactory production of export quality cherimoya (*Annona cherimola*) is dependent on trees with a strong canopy framework and a well established root system. A trial was established to examine the effect of cultivar and seed orientation (sowing seed horizontally or vertically to its main axis) on the germination and seedling characteristics of cherimoya. Over 90% of all seeds germinated but approximately 35% of seedlings had bench roots. However, only 20% of 'Bronceada' seedlings had bench roots, which was significantly lower than 'Burtons', 'Burtons Favourite', 'Bays', 'Smoothey', and 'Reretai' where approximately 40% of seedlings were affected. The cultivars 'Burtons', 'White', and 'Jeté' produced the most vigorous seedlings, although 'White' seedlings had less lateral root development and a higher shoot/root ratio than the other two cultivars. The smallest seedlings were produced from self and cross pollinated 'Reretai' seed. Seed sown horizontally produced more vigorous seedlings with a lower incidence of bench roots than those planted vertically. Although these rootstocks have not been tested in the field, nurserymen should choose cultivars with a low incidence of bench roots, moderate vigour, and a balance between root and shoot growth for seedling rootstocks. Of the cultivars tested in this study 'Bronceada' and 'Jeté' best met these criteria.

INTRODUCTION

The cherimoya (*Annona cherimola*) is grown commercially in California, Chile, and Spain. More recently, plantings have been made in New Zealand and these trees are now beginning to produce fruit. The natural growth habit of the cherimoya produces a large, vigorous, open tree with long weak branches. In a commercial orchard a cherimoya tree must have a strong canopy framework and root system to support and protect approximately 75 kg of fruit. To produce high yields of quality fruit, particular attention must also be paid to pruning (Anderson and Richardson, 1992) and hand pollination is essential (Richardson and Anderson, 1990).

Cherimoya trees are readily propagated by grafting a selected scion onto a seedling rootstock. We have noted that, once trees begin to produce fruit, a high percentage of tree failure is linked to inadequate root systems. This is due to selection of seedlings with a pronounced curvature of the taproot (bench rooted) for rootstocks. A high incidence of bench roots in cherimoya seedlings is linked to the hard, heavily lignified seed coat physically restricting the emergence of the radicle. This problem is exacerbated by the use of shallow containers for seedling production.

The high demand for cherimoya plants in New Zealand has resulted in the use of all available rootstock and scion material. However, in the future, consideration must be given to desirable rootstock characteristics such as high germination rate,

low incidence of bench roots, and the production of moderately vigorous, well balanced seedlings. This study was initiated to determine which of the common cultivars produce the best seedling rootstocks and how seed orientation affects this.

Table 1. Cherimoya cultivars used in the study and their country of origin.

Cultivar	Country of origin
Bays	USA
Bronceada	Chile
Burtons	New Zealand
Burtons Favourite	New Zealand
Chaffey	USA
Jeté	Canary Islands
Reretai (self pollinated)	New Zealand
Reretai (cross pollinated)	New Zealand
Smoothey	New Zealand
White	USA

MATERIALS AND METHODS

Cherimoya seeds were obtained from mature fruit from nine cultivars (Table 1). Fruit used in the study were the result of hand pollination with pollen from a range of cultivars (cross pollination). Seed was also obtained from self pollinated 'Reretai' fruit. All seed was extracted from mature fruit, washed, dried, and stored at room temperature for up to 14 weeks prior to sowing. Seeds were sown in a peat-based mix in 170-mm deep pots on 13 December 1990. Each bin contained 12 seeds, with six seeds sown horizontally to their main axis and six vertically. Each treatment was replicated seven times and pots were regularly randomised within the greenhouse. The seed raising mix was maintained at field capacity and 25°C.

After 7 weeks, the seedlings were removed from the pots and the seed raising mix was washed from the roots. Treatments were evaluated for germination percentage, bench root incidence, shoot weight, root weight, stem length, taproot length, and lateral root development.

RESULTS

A high percentage (>90%) of all seed sown germinated, with no significant effect of cultivar or seed orientation on germination rate (Table 2). A high incidence of bench roots was recorded for all cultivars. However, the cultivar 'Bronceada' had a significantly lower percentage of seedlings with bench roots than 'Smoothey', 'Bays', 'Burtons', 'Burtons Favourite', or cross pollinated 'Reretai'. Seeds sown vertically also exhibited a higher incidence of bench roots than those sown horizontally.

Seedling vigour, determined by weight, varied by up to 50% between cultivars (Table 3). Both 'Reretai' seedling types weighed significantly less than other cultivars. It is of interest that the pollen parents of cross-pollinated 'Reretai' significantly increased the vigour of seedlings, compared to those grown from self pollinated seed. The cultivars 'Burtons', 'Jeté', and 'White' produced the heaviest

seedlings. There was a strong correlation between the average weight of a seed and the seedling produced from it (Fig. 1). However, although 'Bronceada' and 'Smoothey' had the heaviest seeds they were not as vigorous as cultivars with slightly smaller seeds. Seed orientation also influenced seedling weight, with seed sown horizontally producing more vigorous seedlings than that sown vertically.

Table 2. Effect of cultivar and seed orientation on the germination rate and incidence of bench roots in cherimoya seedlings.

Treatment	Germination (%)	Bench root incidence (%)
Cultivar		
Bays	95	40
Bronceada	94	20
Burtons	97	41
Burtons Favourite	99	39
Chaffey	92	37
Jeté	95	27
Reretai (self pollinated)	94	33
Reretai (cross pollinated)	96	38
Smoothey	96	42
White	96	34
SED	3	9
Seed Orientation		
Horizontal	97	31
Vertical	95	39
SED	1	4

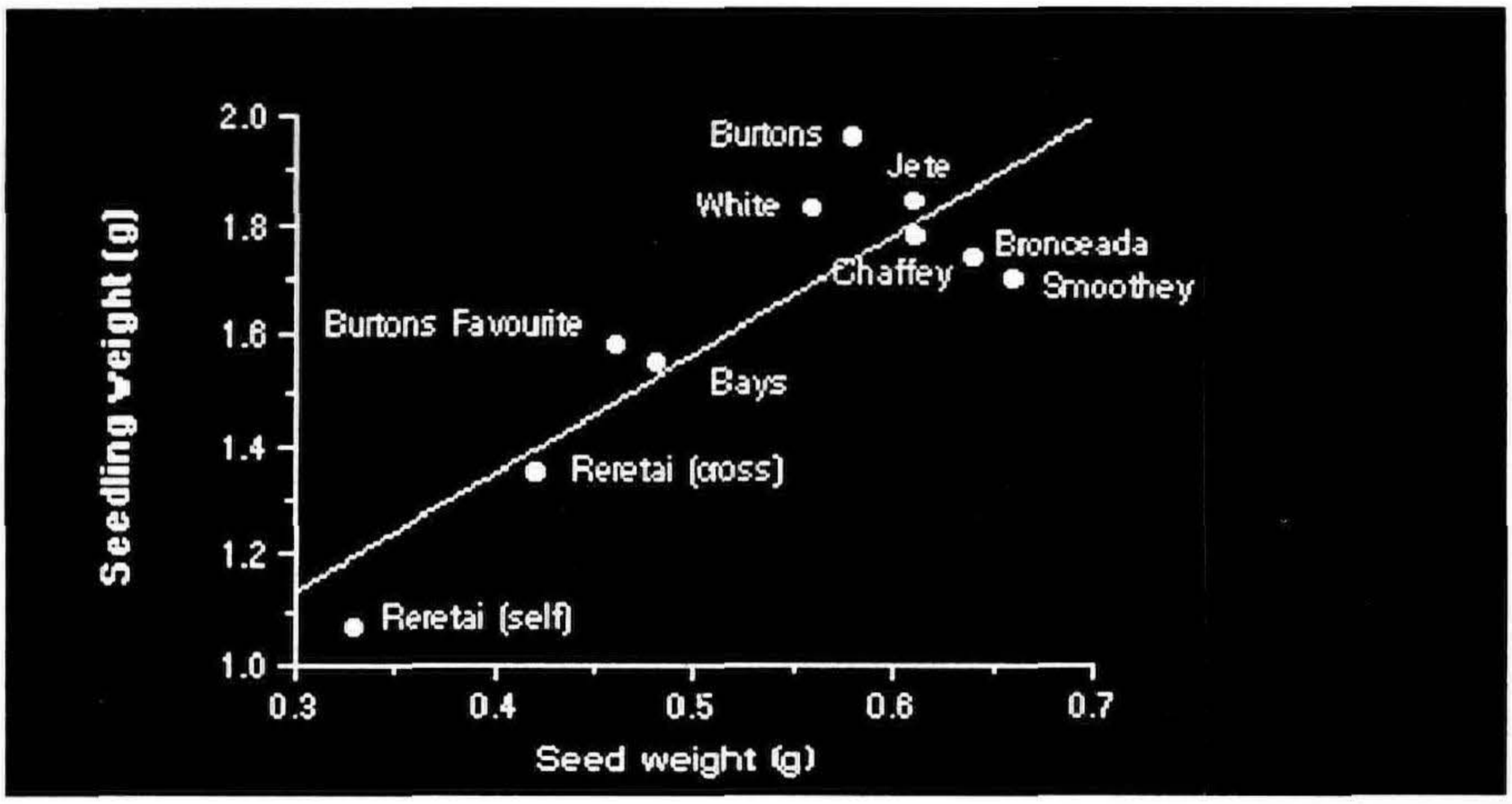

Figure 1. The relationship between seed and seedling weight for several cherimoya cultivars ($y = 0.5 + 2.1x$, $r^2 = 0.75$).

All seedlings had a much higher mass of shoot than root, shown by the shoot/root ratio (Table 3). The Californian cultivars 'Bays' and 'White' both produced seedlings with a higher proportion of shoot than other cultivars. The remaining cultivars had more moderate values. Seed orientation did not alter the shoot/root ratio of seedlings.

Seedling taproot length and the degree of lateral root development varied considerably between cultivars (Table 3). 'Burtons', 'White', and 'Jeté' had significantly longer taproots than other cultivars, while 'Bronceada' and 'Smoothey' had the shortest taproots. However, both 'Bronceada' and 'Smoothey' seedlings had as much lateral root development as most other cultivars.

Seven weeks after sowing, the cultivars 'Burtons', 'Burtons Favourite', 'Jeté', 'White', and 'Smoothey' had significantly longer stems than other cultivars. Both 'Reretai' types had considerably shorter stems, although seedlings grown from cross pollinated seed were more vigorous in this regard. Seedlings with bench roots were as vigorous as those with normal roots. Seeds sown horizontally produced seedlings with longer stems than those sown vertically. The variation in stem length, or the uniformity of seedlings, was not affected by cultivar or seed orientation.

Table 3. Effect of cultivar and seed orientation on the growth of cherimoya seedlings.

Treatment	Seedling weight (g)	Shoot/root ratio	Taproot length (mm)	Stem length (mm)	Lateral root [1]
Cultivar					
Bays	1.55	2.75	154.8	133.0	1.7
Bronceada	1.74	2.19	149.4	131.1	2.0
Burtons	1.96	2.08	175.6	144.0	2.4
Burtons Favourite	1.58	2.15	162.1	138.5	1.8
Chaffey	1.78	2.13	161.8	132.7	1.8
Jeté	1.84	2.00	163.6	140.2	2.0
Reretai (self pollinated)	1.07	1.80	158.1	105.5	1.7
Reretai (cross pollinated)	1.35	2.09	157.2	117.0	1.8
Smoothey	1.70	2.24	147.1	142.3	1.9
White	1.83	2.51	166.4	148.3	1.8
SED	0.08	0.19	6.2	5.5	0.1
Seed orientation					
Horizontal	1.72	2.21	160.3	136.3	2.0
Vertical	1.56	2.16	158.9	130.3	1.9
SED	0.03	0.04	2.5	2.1	0.1

[1] Scored on a scale of 1 = small, 2 = medium, 3 = large.

DISCUSSION

The germination rate of cherimoya seed in this study was considerably higher than either the 30% to 80% range reported by George and Nissen (1987) or the 35% to 90% range recorded in a previous experiment (Anderson, unpublished data). Seeds used in the current study were derived from artificial pollination of flowers with pollen from several cultivars. This may have enhanced the viability of seed, as natural set of cherimoya flowers is very low (Richardson and Anderson, 1990) and low germination rates have previously been ascribed to a high proportion of infertile seeds (Barnes, 1943). Seed extraction and storage procedures can also reduce the viability of seeds (George and Nissen, 1987).

Cherimoya seedlings exhibit varying degrees of bench root incidence which commonly leads to the failure of cropping trees. The cherimoya seed has a thick, heavily lignified seed coat which restricts the emergence of the radicle and thereby induces benching of the taproot (Soule, 1985). Seed size, shape, and resistance of the seed coat vary significantly between cultivars. Although the cultivar 'Bronceada' has relatively large seeds, it appears that the seed coat may not inhibit emergence of the radicle as much as it does in other cultivars. Soaking the seed for 24 to 48 h prior to sowing improves the germination rate and reduces the incidence of bench roots (Sanewski, 1991). Given the tendency of trees to fail through poor root systems, cultivars like 'Bays' and 'White' which have a lower proportion of roots than other cultivars, may produce less stable rootstocks.

The vigour of young seedlings is largely determined by the size of the seed. Although the cultivars 'Bronceada' and 'Smoothey' had the largest seeds, they are less vigorous than other cultivars. This is due in part to slower taproot development in these cultivars which may have inhibited seedling growth. The pollen parent of seeds also affects seed size and seedling vigour, as demonstrated by self and cross pollinated 'Reretai' lines.

Generally cherimoya seeds are sown horizontally to their main axis. Results from this study substantiate this practice as the more time consuming method of placing seeds vertically induces a higher incidence of bench roots and produces less vigorous seedlings. Although this investigation was carried out on 7-week-old seedlings, it suggests there are considerable differences between cultivars. Nurserymen should choose cultivars with a low incidence of bench roots and rogue out seedlings with this deformity, as it will undoubtedly lead to the subsequent failure of cropping trees. Cherimoya cultivars suitable for producing seedling rootstocks should be moderately vigorous with a good balance between shoot and root production. In this study the cultivars 'Bronceada' and 'Jeté' best meet these criteria.

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The Development of Cutting Propagation of *Camellia reticulata* Hybrids

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A dramatic introduction of Yunnan reticulata camellias into Western gardens occurred in 1948 when the Kunming cultivars from China were imported into the United States. This heralded a new era of interest and progress in the cultivation of the genus *Camellia* which has since gained further impetus with the development of new interspecific hybrids, scented cultivars, and the introduction of the yellow-flowered *C. chrysantha*.

These early Kunming reticulatas were traditionally propagated by grafting. Scions were worked onto pot-grown *C. reticulata* or *C. sasanqua* seedlings. Robust, well-established, 3-year-old seedlings, 1 to 2 cm in diameter, were decapitated and either cleft, or, less-commonly rind grafted, to unite scion to rootstock. This was a costly time-consuming, labour-intensive method of propagation. However, it was most successful in producing excellent plants at a time when labour costs were not as high as they are today.

In the early 1970s, increasing costs prompted investigation into finding a more economical propagation method. Cutting-grafts were successfully tried. Good plump cuttings of a *C. reticulata* cultivars, e.g. 'Satans Robe' that had proved to be easily rooted (>80% with 0.8% IBA powder) were made in the usual way, but with a slightly longer shank below the foliage. Onto this unrooted, long-shanked cutting, a side veneer graft was made in the following manner. Approximately 3.5 cm from its base, an oblique angled, straight, clean cut was made about 2.0 cm long. The desired scion cultivar was prepared with an approximately 2.0 cm long, slender wedged base and trimmed foliage. The scion was tied firmly into the incision in the cutting, which was basally wide-wounded in the usual way, treated with 0.8% IBA powder, and inserted into the propagation medium to a point above the union area. Light intermittent misting, moderate humidity, and bottom heat (20 to 23°C) were maintained, as for camellia cuttings. Callus tissue quickly formed and as the cutting rooted, the scion united with it. After approximately 10 weeks, the young cutting graft was untied and potted up. When established with good root development evident, the cutting top was removed above the scion union, leaving the selected culitvar joined to the cutting roots. While a successful method of grafting *C. reticulata*—greater than 70% outturn could be achieved consistently—cutting grafts were a slow and fiddly procedure, and much more labour input was required than for traditional cutting propagation.

In the late 1970s trials were continued with cuttings of the many new *C. reticulata* hybrids that had been introduced along with the original Yunnan cultivars. Different timing and stronger hormone treatments gave us some excellent results. Cuttings from young, barely half-ripe, late spring shoots were made and treated with stronger hormones than usually considered adequate for "soft or green" wood cuttings. Timing was important to obtain optimum results; when cutting wood was in prime condition, some excellent rooting percentages were achieved. Further trials confirmed that barely half-ripe, very pliable green-wood cuttings, basally

wide-wounded, and treated with IBA powder (0.8 to 1.0% up to 2.0% with talc base containing Captan) gave very acceptable results (Table 1). The resulting rooted cuttings produced good, vigorous, saleable young plants in 18 months for PB5 grade (3 litre) or 30 months for PB12 (7.5 litre). They were nicely branched young trees.

Table 1. Rooting of selected *Camellia reticulata* cultivars.

Cultivar	IBA (talc based) (%)	Weeks from sticking to potting	Rooting (%)	Sticking date
Buddha	1.0	18	90	Nov
Buddha	0.6	18	40	Feb
Butterfly Wings	0.8	12	35	Dec
Ghittagong	0.8	12	72	Dec
Curtain Call	0.8	10	90	Dec
Curtain Call	0.8	10	43	Feb
Doctor Clifford Parkes	1.0	16	83	Feb
Doctor Clifford Parkes	0.8	16	48	Apr
El Greco	0.8	14	66	Dec
El Greco	0.8	12	25	Mar
Howard Asper	1.0	10	65	Dec
Howard Asper	0.8	12	30	Mar
LASCA Beauty	2.0	14	74	Apr
Miss Tulare	1.0	13	88	Dec
Pagoda	1.0	18	73	Nov
Pagoda	0.8	18	20	Mar
Royalty	0.8	12	62	Dec
Satan's Robe	0.8	12	80	Feb
Terrell Weaver	1.0	12	71	Dec
Valentine Day	2.0	16	52	Apr
William Hertrich	1.0	12	93	Dec
William Hertrich	0.8	12	52	Mar

In this way the production of *C. reticulata* cultivars can be achieved without costly grafting techniques, without the cost and need for producing compatible understocks, and with much more cost-effective labour input.

The Influence of Watering, Shading, and Nitrogen Levels on the Growth of Container-Grown *Schlumbergera* × buckleyi

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Container-grown *Schlumbergera* × buckleyi grown in 6 peat : 4 sand (v/v) medium grew more strongly at 60% or 80% container capacity watering levels than at 40%. Flowering was also greater at the two higher watering levels. In a second experiment, 40% and 75% shading reduced growth over the autumn and winter growing period; however, unshaded plants were not as green as those under shade covers. Nitrogen (N) fertilisation above 300 g N·m^3 or equivalent to 40 g N·m^3 month, depressed growth. It was recommended to maintain media at 60% container capacity, to use a low level of shading to improve plant quality especially over summer, and to use low N rates equivalent to around 35 g N·m^3·month.

INTRODUCTION

The Christmas cacti are common flowering pot plants grown primarily for autumn and winter sales. There has been much confusion over the naming of these plants. The true Christmas cactus, *Schlumbergera* × *buckleyi* is a hybrid between *S. truncata* (the Thanksgiving cactus) and *S. russelliana*. Previously it was called *S. bridgesii*. The true Christmas cactus characteristically has scalloped-edged stem-segments (phylloclades), while those of the Thanksgiving cactus are toothed. The latter has been previously known as *Epiphyllum truncatum* and *Zygocactus truncatus*. Much hybridisation has taken place with these plants and many cultivars are derived from crosses between Christmas and Thanksgiving cacti. Collectively they are commonly known as Christmas cacti, holiday cacti, schlumbergeras, and zygocactus and their cultural requirements are similar.

The true Christmas cactus is an epiphytic member of the Cactaceae family. The natural habitat of the parent species is in the rainforest of the peripheral mountain ranges of eastern Brazil, just north of Rio de Janeiro. These plants grow at an altitude of 900 to 1800 m. As epiphytes, or surface growers, they cling onto the stems and branches of forest trees, absorbing as much water and nutrients from the accumulation of humus (decaying organic matter) as possible. Roots are kept well aerated, while the moist air prevents the roots from drying out. Their stem-segments function as leaves but do not as readily loose moisture by transpiration. Living in the tops of trees they get good, but filtered, light.

There has been little research into the cultural requirements of Christmas cacti. Experimental work has mainly concentrated on chemical, photoperiod, and temperature manipulation of flowering, while other recommendations are often based on grower experience. Boyle (1990) and Hammer (1980) suggested that Christmas cacti should be irrigated frequently to retain a moist growing medium for maximum

growth. This recommendation is qualified in that the media must be high in organic material and well drained. Discussing potting mixes in general, Bunt (1976) suggested that a progressive reduction in growth will occur when plants, in general, receive an excessive amount of irrigation as the air capacity of the substrate is reduced to below 10%. Working with ferns, Khoo (1979) found that *Asplenium bulbiferum* grew better at 60% container capacity whereas *Adiantum raddianum* was superior at 80%.

Some growers recommend a drying-off period in early autumn to help induce flower bud formation, with plants only being watered if excessive wilting occurs. Normal watering is recommenced once tiny flower buds appear (Burke, 1983; Slade, pers. comm.). Boyle (1990) reported that this recommendation had not been supported by research and suggested that plants should not be allowed to shrivel or be overwatered during flower induction treatments. He also said the saturation of growing media for prolonged periods will reduce aeration and predispose the roots to attack by soil-borne diseases. Andersohn (1983) also stated that the Christmas cactus was sensitive to waterlogging and extreme drying of the root ball. Heins et al., (1981) concluded that the practice of moisture stressing Christmas cacti during flower initiation may have originated as a process of controlling disease, but became associated with inducing flower bud formation. They found the number of flower buds was reduced by high water stress during flower initiation.

The general recommendation for growing Christmas cacti is that they should be grown in full sun, but shaded from October to March, or from April to September in the Northern Hemisphere (Andersohn, 1983; Boyle, 1990). Boyle (1990) suggested that the light intensity should be maintained in the range of 15 to 30 klux, while Anon. (1991), suggested 15 to 25 klux. McConnell et al. (1981) reported plants being grown at 30 to 40 klux.

Work on African violets indicated they could be grown in reduced light of 50% to 70% shading, then exposed to higher light levels with 30% to 50% shading, to promote increased flower numbers (Anon., 1981). Thomas and Teoh (1983) found that reduced growth occurred with *Ficus macrophylla* when plants were grown under 40% and 75% shade. At no shade, increasing nitrogen (N) levels strongly promoted top growth, but at high shade, there was little or no effect. Nitrogen applied at 86 to 110 g $N \cdot m^3$ month gave best growth and quality. Working with ornamental peppers, Thomas and Leong (1984) found that high quality plants could be produced at 50 klux light level (0% shade) and 600 g $N \cdot m^3$. With ferns, Khoo (1979) reported no significant interaction between N levels and light intensity. *Asplenium bulbiferum* required a higher light level (12 to 16 klux) than *Adiantum raddianum* (6-10 klux). An N application of 100 to 120 g $N \cdot m^3$ month was recommended.

Reports generally indicate that the Christmas cacti have relatively low nutritional requirements. Boyle (1990) recommended watering with 100 to 150 ppm N one to three times a week using a balanced N-P-K fertiliser. Another report (Anon., 1991) suggested N levels should be maintained between 75 to 125 ppm until plants have reached their desired height, at which time the fertiliser application should be halted during flower initiation, and then resumed with a low N ratio fertiliser. Proprietary fertilisers, used at half the recommended rate, were suggested as being suitable by Burke (1983) for home gardeners growing the Christmas cactus.

Backeberg (1976) said the use of an inorganic fertiliser which was low in nitrogen, but richer in phosphorus and potassium, would promote growth and better bud development.

Two experiments were carried out to investigate the effects of water, shade and nitrogen levels on the growth and development of the true Christmas cactus, *Schlumbergera* × *buckleyi*.

EXPERIMENT 1: WATERING

Potted plants were grown for 12 months under one of three watering regimes in which the medium was maintained at either 40%, 60%, or 80% container capacity.

Materials and Methods. Rooted cuttings, consisting of four to five stem-segments, were placed in 125-mm plastic pots lined with polythene to prevent water loss. Each pot was filled with 800 ml of air-dried potting mix based on 60% Southland (Mataura) sphagnum peat and 40% coarse manufactured sand. A standard fertiliser mix had been added based on an 8-9 month release "Osmocote" compound fertilizer. Each pot was check weighed and adjusted to 611 g of potting mix.

A few pots were weighed at 100% container capacity and from this (by deducting the weight of oven dried mix), a weight was determined at which each treatment replicate should be maintained to give 40%, 60%, and 80% container capacity. This figure included a total weight for the pot, polythene, label, fertiliser, medium, and plants. A sample of plants, top and washed roots, was weighed and found to have a mean weight of 11 g per plant.

The experiment was set up in December (summer) and carried out in a heated glasshouse with automatic fan ventilation. The minimum glasshouse temperature was 15°C while the maximum was approximately 5°C above ambient temperature. The plants were grown under 50% shadecloth. Each treatment consisted of five replicates of two plants per pot arranged in a randomised block design.

Pots were weighed each day. If any individual replicate had dropped below the treatment container capacity weight, it was rewatered to 10 g above this weight. Periodically the weight was adjusted for any increase in plant size.

Growth and flower assessments were carried out at various stages during the experiment with a visual rating being carried out just prior to harvest in November (after 12 months). This was based on a 1 to 5 scale for vigour and general appearance, with a very vigorous and high-quality plant being given a rating of 5. After harvest plant tops were oven dried and weighed. Results were analysed using computer programme Genstat 5.

Results. Container moisture levels had a strong influence on growth and development (Table 1). There was a highly significant increase in stem-segment numbers, dry weights, and visual ratings, from 40% to 80% container capacity, although there was no significant difference between 60% and 80% container capacity. The effect on stem-segment numbers became more significant with time. While there was a significant increase in flowering between 60% and 80% container capacity, flower numbers per plant were low.

Table 1. Effect of watering regime on the growth and development of the Christmas cactus.

Water regime (% container capacity)	Stem segment (number) Months after setting up 1	4½	6½	12	Visual rating	Dry wt (g)	Flower number
40	8.4	27.2	40.7	90.0	3.0	7.40	1.2
60	8.6	32.8	52.0	129.8	3.6	10.06	1.0
80	9.2	35.2	48.7	134.4	4.0	10.48	3.2
Significance	-	#	**	***	**	***	**
LSD (5%)	3.6	7.3	6.5	16.7	0.5	0.47	1.2
CV %	28	16	9	10	9	3	46

Significance levels: ***p<0.001; **p<0.01; *p<0.05; #p0.05-0.1
All figures are per plant.

EXPERIMENT 2: SHADE AND NITROGEN RESPONSE

In this two factor experiment plants were grown under three levels of shade (0%, 40%, and 75%) and in three levels of nitrogen (N) fertiliser (300, 600, and 900 g total $N \cdot m^3$). The plants were arranged in a split-plot design.

Methods and Materials. Tubelings of approximately 25 stem-segments were potted into 125 mm plastic pots containing the three levels of nitrogen. A medium of 60% Southland (Mataura) sphagnum peat and 40% coarse manufactured sand was used. The following base fertilisers were added per m^3 of mix: 2.5 kg superphosphate (9% P); 427 g sulphate of potash (39% K); 4.5 kg Dolomite lime; 1.5 kg agricultural lime; 150 g Sporumix A (trace elements); and 360 g Fetrilon (iron chelate). In addition Osmocote 26-0-0 (26% N), with a 3-4 month release period, was applied at three rates: 1,154 g, 2,300 g, and 3,462 g per m^3 providing 300, 600, and 900 g $N \cdot m^3$, respectively. Half of these rates were incorporated initially into the mixes with the rest being applied as a side dressing after 3½ months. Twenty-one plants, with one plant per pot, were potted into each nitrogen level.

The experiment was carried out in similar glasshouse conditions to the previous experiment except for the shading. Hand watering was carried out when required.

Seven plants from each nitrogen level were treated to either 0%, 40%, or 75% shade. Average maximum light levels during the running of the experiment were estimated to be 312, 187, and 78 W m^2 (41 klux, 24 klux, and 10 klux) for the 0%, 40%, and 75% shade levels, respectively.

The experiment was set up in March and plant stem-segments were counted at this stage and just prior to harvesting in October, after 32 weeks of growth. At this stage plants were visually rated for quality and vigour (as per the watering experiment) and for chlorosis. The latter was based on a 1 to 5 scale with a score of 1 for pale chlorotic foliage and 5 for dark green foliage. A flower count was also carried out and on harvesting, plant tops were oven dried and weighed. Data were

analysed using the Genstat 5 computer programme.

Results. Shading had a negative effect on growth as shown by reduced stem-segment numbers and, in particular, top dry weights (Table 2). There was no significant difference (at the 5% level) in dry weights between no shade and 40% shading. Shading had no significant effect on overall vigour and quality (visual ratings), with the significantly greener plants obtained under heavy shade (chlorosis ratings) compensating for the reduced plant size. Although flower numbers were greatest at 40% shade, there was great variability between replicates and results were not significant.

Increasing nitrogen levels depressed growth although this was only shown to be significant in dry weights. Plant quality was also reduced, as shown by a reduction in visual ratings. These effects were most significant when the nitrogen level was increased from 300 to 600 g $N \cdot m^3$. Increasing nitrogen from 300 to 900 g $N \cdot m^3$ had no significant effect on stem-segment numbers, chlorosis ratings, or flower numbers.

Table 2. Effect of shade and nitrogen levels on the growth and development of the Christmas cactus.

Factor	Stem-segment number	Visual rating	Chlorosis rating	Dry weight (g)	Flower number
% Shade					
0	78.1	3.5	2.4	8.53	1.9
40	71.5	3.5	3.3	7.53	3.6
75	63.1	3.3	4.6	5.18	1.4
Significance	*	-	***	***	-
LSD (5%)	9.66	0.66	0.71	1.33	2.67
CV %	12	16	17	16	98
Nitrogen g·m3					
300	76.1	3.9	3.4	8.06	2.7
600	68.1	3.2	3.5	6.70	1.6
900	68.4	3.3	3.6	6.48	2.5
Significance	-	*	-	**	-
LSD (5%)	11.07	0.56	0.43	1.06	1.44
CV %	25	26	20	24	99

Significance levels: ***p<0.001; **p<0.01; *p<0.05; #p0.05-0.1
Analysis adjusted for initial stem-segment number covariate.
There was no significant interaction between shade and nitrogen.

DISCUSSION

Results from the watering experiment support the recommendation for growing Christmas cacti under moist conditions (Hammer, 1980; Boyle, 1990). However, as there was no significant difference between maintaining the plants at 60% and 80% container capacity, there appears to be little benefit in high moisture levels

(80% container capacity) if there is a greater risk of soil-borne disease infection. Any potting mix that is used should be well drained and well aerated. While flower numbers were greatest with high media moisture conditions, numbers were generally low. Flowering could be promoted by the use of chemicals, e.g. 6-benzyladenine, and alterations to photoperiod and temperature (Anon., 1991). From other studies (Heins et al., 1981), there appears to be little evidence to support the use of a dry-down period during flower initiation to encourage more prolific flowering.

It has been suggested that Christmas cacti be grown in full sun except in summer when some shading is desirable (Andersohn, 1983; Boyle, 1990). In the second experiment, which was carried out from autumn to spring, maximum growth was achieved with no shade. However, plants with no shading were also more chlorotic suggesting decreased chlorophyll content as discussed by Thomas and Leong (1984). Results tend to indicate that where good natural light transmittance occurs in the greenhouse some shading may be beneficial, even outside the summer months. Plants were significantly greener, but not significantly smaller, when given 40% shade. A higher level of shade may reduce growth except under summer conditions. Even at 40% shading, in this experiment, light levels were probably within those that have been recommended (Boyle, 1990; Anon., 1991). Under greenhouse conditions where natural light levels may be lower, no shading may be necessary, except over the summer period.

Results show that the Christmas cactus is sensitive to even medium levels of nitrogen and should be grown with a low nitrogen base fertiliser or liquid feed. Beyond 300 g total $N \cdot m^3$ (or 40 g $N \cdot m^3 \cdot$month) there was a significant depression of growth. This supports the claim that these plants have a low nitrogen requirement (Backeberg, 1976; Burke, 1983). Unpublished work by the authors on the same species indicated growth response to nitrogen peaked at around 35 g $N \cdot m^3 \cdot$month. This rate is low compared to recommendations for some other species (Khoo, 1979; Thomas and Teoh, 1983; Thomas and Leong, 1984). Comparative liquid feed rates of around 100 ppm N seem appropriate when Bunt (1976) spoke of normal rates of 200 ppm.

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Mass Propagation of *Smilax oldhami* Miq. by Tissue Culture

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A donor plant was produced aseptically by culturing a nodal segment of an in vivo *Smilax oldhami* Miq. plant. From the donor plant, segments of nodes, internodes, and roots were taken and cultured on a modified Murashige and Skoog (MS) basal medium. Hormonal effects on shoot formation and rooting were investigated. The rate of propagation from the internodal segment was higher than that from the other two types of explants. It could be concluded from the data in the present culture system that more than 75 plantlets were obtained from one nodal segment of an in vivo plant.

INTRODUCTION

Smilax oldhami Miq. is a perennial plant of the liliaceae family. In Japan, the plant grows indigenously in forest regions from Kyushu to the northern districts and is called "shiode". The young leaves and shoots of the plant are used as a fried food and as boiled greens with dressing for its fine flavour. Propagation of the plant from seeds is difficult. Recently, we reported methods for mass propagation of the plant by tissue culture (Yamamoto and Oda, 1992). Somatic embryos, induced directly on the surface of leaf explants, were considered to be effective for the mass propagation of the plant. However, embryogenesis was sporadic and it took about six months to occur. The present paper describes the in vitro regeneration of shoots from seedling shoot and root explants.

MATERIALS AND METHODS

A donor plant was produced aseptically by culturing a nodal segment (3 mm in length) taken from an in vivo plant. The methods for sterilization and composition of medium were same as those described previously (Yamamoto and Oda, 1992). From the donor plant in vitro segments of node, internode (10 mm in length), and root (10 mm in length) were taken and placed on each medium. Nodal segments were cultured on 1/2 Murashige and Skoog (MS) medium without hormones. Internodal explants were cultured on MS medium supplemented with BA (6-benzyladenine) (1 mg/l) and/or 2,4-D (2,4-dichlorophenoxyacetic acid) (1 mg/l) for two weeks, then transferred to hormone-free medium. Root segments taken from proximal, median, and distal parts of the root, were cultured on MS medium containing cytokinin and auxin. Hormones used were BA, KIN (kinetin), ZEA (zeatin), NAA (naphthaleneacetic acid), IBA (indolebutyric acid), and 2,4-D. The

concentrations of these hormones were adjusted to 0.1 mg/l, because it had been already reported that low concentrations of hormones were effective for shoot formation from root segment (Lazzeri and Dunwell, 1984a; b; 1986; Chen et al., 1987; Dubois et al., 1990). Cultures were kept at 25°C and 16-h photoperiod. For acclimatization, the regenerated plants were transferred to pots (9 cm in diameter) containing vermiculite.

RESULTS AND DISCUSSION

Axillary buds were easily induced from lateral meristems within a short period. After 17 days of culture on 1/2 MS medium without hormones, the ratio of the explants with shoot to those cultured was 0.92, and cytokinins such as BA and KIN had little effect on axillary bud induction.

Table 1. Effect of BA and 2,4-D on shoot formation from internodal segments.

BA (mg/l)*	2,4-D (mg/l)*	Explant with shoot %	Number of shoots per explant
0	0	28	0.5
0	1.0	100	8.2
1.0	0	24	0.2
1.0	1.0	21	0.2

Each value was scored after 100 days in culture.
* These hormones were supplied for the initial two weeks of culture.

As shown in Table 1, the highest shoot formation from the internodal segments was achieved by the treatment of 2,4-D for an initial two weeks of culture, and the average number of shoots per explant was 8.2. The shoots regenerated were regarded as adventitious shoots formed directly from the explants. The effects of 2,4-D on shoot formation were more favourable than those of BA and NAA reported previously (Yamamoto and Oda, 1992).

Table 2. Shoot formation from root segment.

	Explants with shooting (%)		Number of shoots per explant	
	Days in culture			
Root segment	35	70	35	70
Proximal	30	80	1.0	4.9
Median	30	70	0.6	4.9
Distal	0	20	0	0.4

The root segments were placed on the various media with nine combinations of cytokinins and auxins. The formation of embryogenic callus was observed only for combinations of BA and NAA. The data for shoot formation are shown in Table 2. The frequency of shoot formation was highest in the proximal region of the original root. This is consistent with the observations for *Brassica oleracea* and *B. napus* (Lazzeri and Dunwell, 1984a; Sharman and Thorpe, 1989). After 70 days in culture the number of the shoots regenerated averaged 3.4 for the three segments.

Table 3. Ratio of the shoots rooted to those cultured in rooting medium.

Type of explant	NAA in rooting medium (mg/l)	Days of culture in rooting medium	
		30	45
Node	0	0.0	0.1
	0.5	0.8	0.8
Internode	0	0.6	0.9
Root	0	0.7	1.0

Table 3 shows the ratio of the shoots rooted to those cultured in rooting medium. A marked effect of NAA was observed on the rooting of shoots induced from nodal segments. In a previous experiment, it was observed that auxins were necessary for the rooting of shoots induced from nodal segments, and that NAA was better than IAA (indoleacetic acid) and IBA (Fukuda et al., 1990). On the other hand, shoots regenerated from internode and root explants easily rooted on 1/2-strength MS medium without auxins. The rooting ratios for shoots regenerated from internodal and root segment were 0.9 and 1.0 after 45 days of culture, respectively.

Figure 1. Smilax plantlets after acclimatization.

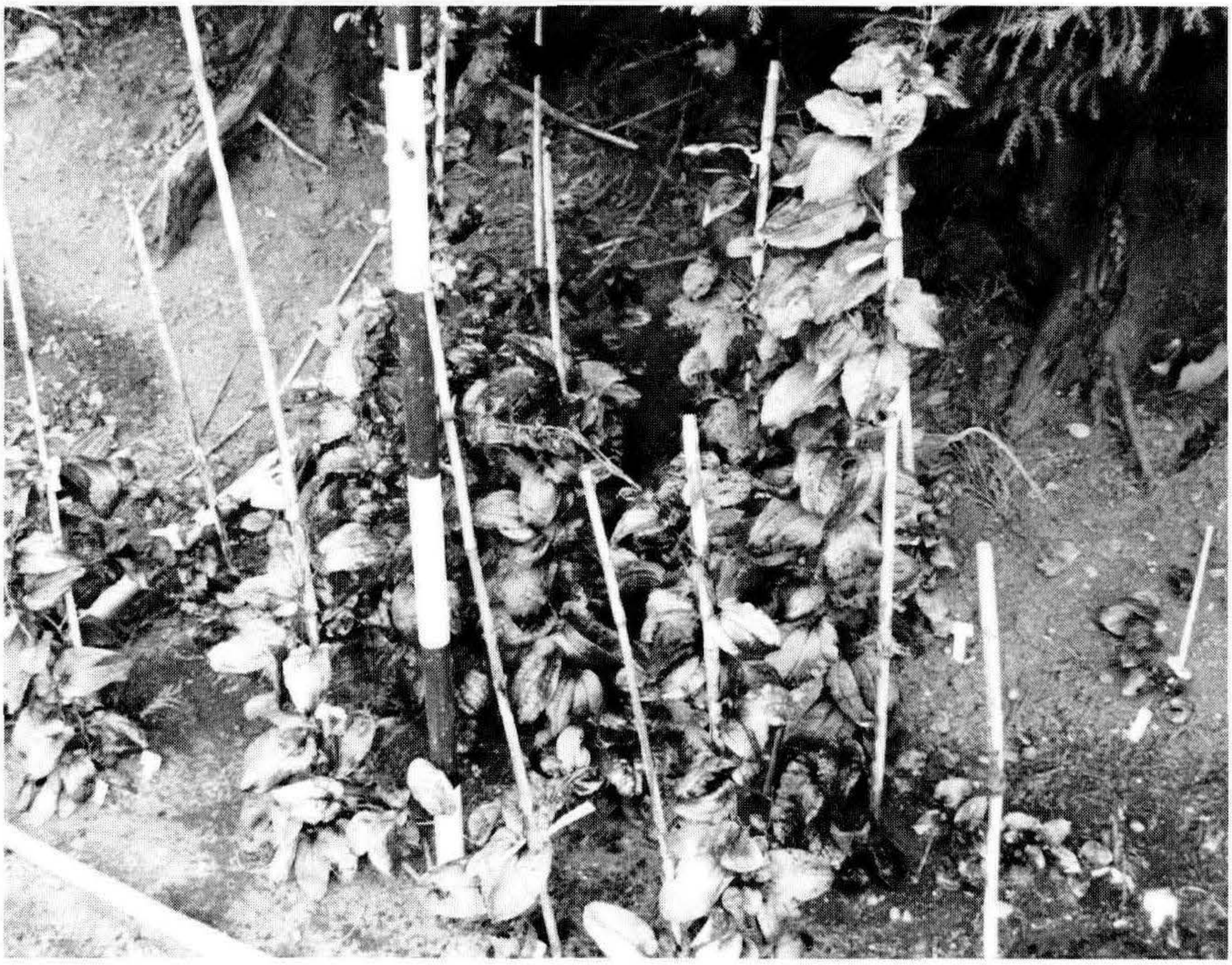

Figure 2. Growth of the plants propagated by the tissue culture.

The number of plantlets produced per explant (P) is an important index for planning practical propagation. When the propagation was carried out from one type of explant, the rate of propagation P can be expressed by the following equation: $P = S \times R \times f \times A$, where S is the number of shoots regenerated per explant, R is rooting ratio, f is the ratio of the plants available for acclimatization to those regenerated in vitro, and A is the acclimatization rate. From our research and experience, we consider values for f and A of 0.9 and 1.0, respectively, to be correct. As shown in Table 4, the rate of propagation from the internodal explant was higher than those from the other two explant types.

Table 4. Rate of propagation from node, internode, and root explants.

Type of explant	Number of shoots formed (S)	Rooting (R)	Rate of propagation (P)	Number of explants* (N)	(P × N)
Node	0.9	0.84	0.70	6	4.2
Internode	8.2	0.93	6.90	5	34.5
Root	3.4	1.0	3.06	12	36.7

P = S R f A (f = 0.9, A = 1.0) The sum of (P × N) = 75.4

* The explants were taken from an in vitro donor plant.

The number of explants obtained from the donor plant in vitro (N), and the product of N and P are also shown in Table 4. The value, N × P, corresponds to the number of plantlets produced per N explants of a type taken from the donor plant. Accordingly, the product N × P of 75.4 can be regarded as the total number of plantlets produced from a nodal segment of an in vivo plant, indicating the rate of propagation from the explant in the present culture system. This is a rough estimation, because some shoots were subsequently regenerated after cutting off the shoots formed before. Taking this point into consideration, it could be concluded that in the present culture system more than 75 plantlets were obtained from one nodal segment. Consequently, if the 75 plants regenerated in vitro are used as new donor plants, more than 75^2 plantlets will be obtained several months later. The plants propagated by this culture system have grown normally in soil for more than three years. Figures 1 and 2 show the plantlets acclimatized and the plant growing in the soil, respectively.

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Development of a Prototype Automated Cutting and Placing System for Tissue Culture Multiplication

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A prototype cutting and placing device has been developed at the New Zealand Institute for Crop & Food Research Ltd and the Agricultural Engineering Institute. *It is not intended to be a complete tissue culture system* but it may be able to be integrated into existing laboratory procedures. The workstation comprises a vision system, a robotic arm incorporating the cutting device, and computer control hardware. It is mobile and can be situated adjacent to a laminar flow cabinet enabling the robotic arm to move into the cabinet to operate. The robotic hand has been designed for the compact multi-meristematic form of plantlet growth in conjunction with a range of conventional plastic tissue culture containers. Preliminary tests have shown good growth of explants subsequent to cutting and placing with the robot, and 0.9% contamination compared with 1.7% when cut and placed manually.

INTRODUCTION

Micropropagation is a labour-intensive method of producing plants and a large proportion of the total cost can be labour. A number of automated tissue culture systems have been developed but few are currently in use commercially (Aitken-Christie, 1991). There have been some sophisticated systems developed, but economic feasibility has not often been a consideration (Kurata, 1992). We perceived a need for a machine that was inexpensive, mobile, and would fit into a conventional laminar flow hood. The machine developed here was not intended to be a complete tissue culture system, but one that would be able to be easily integrated into an existing laboratory. The programme was funded under the Foundation for Research Science Technology Priority Research Contracts Scheme and work was jointly performed by Crop & Food Research and the Agricultural Engineering Institute. It focused on the cutting and handling aspects of micropropagated plantlets. The associated tasks of handling containers was not part of this programme, as there are a number of conveyor belt systems available that have been designed to move containers and these could be adapted if necessary. This programme targeted the compact multimeristematic form of plant growth in tissue culture as it is the simplest to automate.

Figure 1. Prototype robot situated in laminar flow hood.

THE ROBOTIC SYSTEM

The workstation consists of the robot and a robotic hand, a vision system, a computer, and software written for the operation of our machine (Fig. 1)(Kerr et.al,1992). It is mounted on a trolley, adjacent to the laminar flow hood, so that it is mobile and can be easily moved. For pragmatic reasons, it was decided to buy an off-the-shelf Mitsubushi RVM1 vertical articulated robot with 5 degrees of freedom, operated by the robot controller or hand held teaching box. The load capacity is 1.2 kg, accuracy ± 0.3 mm, maximum speed 1 m/sec. The software directs the robot, issuing speed and position information. Coordinates are defined externally for fixed locations such as the source container location, planting positions, and sterilizer. Plantlet locations, identified by the vision system, are communicated to the robot by the software.

The computer is an IBM compatible 386 SX PC, with i/o cards to operate the pneumatic system. The software coordinates and controls all the other components of the system. The testbed software is implemented with Microsoft C, and Cscape screen libraries. The system has pull down menus, editing screens for system parameters, and scripts for sequencing actions. The scripts provide the flexibility to change sequences and timing without making coding changes. Two methods for invoking scripts are implemented — single pass and repeated. Single pass scripts allow the setting up of sequences for initialising the apparatus and testing components. The repeated scripts start from the beginning and, after reaching the end, return to the beginning allowing for production sequences.

The imaging system employs a Matrox IP-8/AT video graphics system board connected to a CCD camera, providing 256 grey scale images through a Fujinon 12.5 to 75 mm zoom lens. Diffuse back lighting was employed to obtain good

Figure 2. Robotic hand shown here cutting *Eucalyptus camaldulensis*.

contrast of the plant material compared with the background. An image is obtained from the vision routine and thresholded to produce a binary image. The threshold used is predetermined, and adjustment made to the image through the aperture and focus setting. Radial scan lines are traced from the edge to the centre of the petri dish at specified intervals, to contain each plantlet within a sector. Each resultant sector is scanned, and the pixels, representing plant material, are averaged to determine the centroid.

The hand is an integrated device, which cuts, transports, and places the explants into fresh media (Fig. 2). The three-bladed cutter is directed to the centroid and presses down onto the plantlet (still in its original container) to divide it into three explants. These are each held by a needle and a finger. The hand moves across to the new container and the explants are deposited in sequence evenly spaced on a 50 mm pitch diameter. Explant release is effected by a pusher which presses the explant into the media. This sequence repeats filling the preset positions in the container. Fresh containers of plantlets and new media are requested when required. The hand is pneumatically operated and constructed from stainless steel, gauge plate and has plastic (PEEK) pushers.

A wash and sterilization sequence, to sterilize the cutting hand, can be scheduled as required. Currently this occurs before a source container of plantlets is processed. The cutter is first immersed in ethanol that is agitated by an air sparge to dislodge pieces of plant material and media. Then the robot traverses to the hot bead sterilizer where the cutter is sterilized at 250°C for 20 sec. A pulsing sequence after each operation shakes off excess ethanol and glass beads.

PROGRESS TO DATE

We have used three species, *Asparagus officinalis, Eucalyptus camaldulensis*, and a *Zantedeschia* hybrid (calla lily), in our trials. Their growth form was manipulated by changes in media components to achieve the compact multimerisematic form for the multiplication phase (Grant et al., 1992). The containers we routinely use are clear plastic petri dishes (90 mm diameter × 14 mm deep) and tubs (95 × 60 mm), but the robot will operate in other containers when parameters such as explant position, planting depth, and container dimensions are changed. The plantlet layout within the container is set at six plantlets equidistant on the circumference of a 50-mm diameter circle. However, this layout was designed to be flexible and can be changed by the user.

The system is operational and initial tests have been conducted. So far, after the production of 1,400 explants by the robot, there has been 0.9% rate of contamination using the robot which is less than the manual rate at 1.7% for the same number produced. The operational rate of the robot is approximately 18 sec per explant, which is approximately 180 new explants produced per hour. With parallel processing of the imaging while the robot operates, time taken to yield one explant should reduce to approximately 14 sec. The robot at the moment only operates at about 30% to 40% of full speed. Speed will be increased at a later date when current trials have finished. A pilot study to compare growth, health, and contamination rates of robot-cut plantlets versus manual-cut plantlets over four subculture cycles is underway. Growth is being assessed twice weekly using image analysis, and quantitative data will be collected.

A three-bladed cutter was chosen because a 3-fold multiplication rate was an average rate in a 2 to 3 week subculture cycle. When a species has a fast growth rate, for example *Zantedeschia*, subculture is at 2-week intervals. *Asparagus officinalis* and *E. camaldulensis* are subcultured at 3-week intervals. Some investigation is needed to optimise length of subculture period. We planned to have interchangeable or removable cutter heads to allow for differing plant types, varying growth rates, and to enable sharpening. However, our prototype has operated for 4 months with the original stainless 3-bladed cutter. When the cutter was tested on a rhododendron cultivar 'Surrey Heath' and a *Rubus* hybrid 'Kotata', it initially cut the material, but in later trials it was unsuccessful. Improvements to the cutting blades would be needed to deal successfully with woodier species. Laser cutting has been successfully used in several systems (Holdgate, 1992) and could be an improvement, solving the problem of cutting woody species.

With regard to machine vision, the present radial lines system cannot distinguish between overlapping plantlets and, as a result, a group of such plantlets are treated as one. The number of explants per container was set at six due to the limitations of the vision system; however, we would anticipate putting many more explants per container in a commercial operation with an improved vision system. A new image processing programme is now available and should be substituted to distinguish effectively the original individual clumps when overlapping occurs. Other improvements such as automatic thresholding of the image to maintain image quality could also be incorporated.

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The Role of the Plant Propagator in the Conservation of New Zealand Plants

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In many countries nurseries have developed from small businesses run by plantsmen into organisations where the primary interest is in the production of a healthy bottom line on the bank statement. The need for plants has to a greater or lesser extent become a secondary consideration in a production-driven operation directed by people with relatively little plant knowledge.

The importance of plants and productivity has long been recognised. However, the nursery industry is in danger of being market-led to the extent that people neglect to conserve plants for use by future generations. This is evident from the trade lists that now have fewer of the more difficult to propagate and grow on plants than has been available in the past.

Throughout the world plants once considered common place are now becoming endangered. If we as propagators do not make a concerted effort to propagate and protect these plants, they will become increasingly threatened by extinction and be lost forever as a resource for future generations.

It is especially important that we do not limit the range of plants propagated to those in most demand at the present time as we cannot anticipate future interests or requirements with any real certainty. The extensive range of plants grown throughout the world makes it nearly impossible to describe how each may best be propagated. In spite of the enormity of the task it is still highly desirable that all relevant information of this type be collected and made available to others with similar interests such as within the I.P.P.S. and wider afield.

This information is important and may be lost if it remains only in the head of each propagator. Each plant species may have its own unique requirements for propagation by seed or by vegetative methods that has been discovered by empirical methods. Experience gained in this manner may often be usefully applied to other species, in both the easy and the more difficult plants to propagate.

Plant propagators hold the keys to both the preservation of many indigenous species and the commercial exploitation of economically important plants. Some of these plants (particularly some native plants) have gained a reputation of being difficult to propagate and grow, so they drift out of the market place and, if fortunate, are preserved by specialist propagators.

If you wish to help conserve some relatively rare plants in your area or just wish to propagate some plant you will need to determine an appropriate procedure. In the absence of specific information pertaining to a particular species or cultivar you may be forced to experiment. Many plants have specific propagation requirements and trial and error may be the only method of producing some plants until you have gained more experience.

Just how threatened are the plants of our world? It has been estimated that at present the global consumption of wood for fuel and building use sees an area the size of New Zealand is converted into a barren desert every four years. As a consequence many plant species have disappeared in the path of desertification in

the name of progress. A quarter of all the world's flowering plants may become extinct within the next 50 years. As an aside, millions of people depend on plants for their traditional medicine. Over 80% of all prescribed medicine is of plant origin, but only 5% of the plants in the world have been examined chemically or pharmacologically. If they become extinct their genetic potential may be irretrievable. In New Zealand we are not exempt from this problem, but are also contributing to it. Forest covered about 70% of New Zealand prior to occupation by people, this has now been reduced to 25% of the total land area. As a result many habitats of plants and animals have been threatened, without even considering the cost of soil erosion to the country. Unfortunately, our record is no better than many developing countries we might chide for careless destruction of their natural resources.

At present approximately 10% to 12% of the flora in New Zealand is in the threatened category (Wilson and Given, 1989). This means that a significant proportion of our flora falls somewhere between the rare and extinct categories used to classify endangered plants (Table 1). About 80% of our natural flora is endemic and therefore unique to the region. Therefore as propagators we have a national responsibility to help wherever possible to use our skills to help conserve our native flora for future generations.

Table 1. Categories of threat to endangered plants.

Rare:	A relatively small total number plants but not currently at risk.
Vulnerable:	A species that may move to the endangered group in the near future if pressures on numbers or habitat continue unabated.
Endangered:	Number of individuals in a plant population is below a critical level and survival is unlikely without intervention.
Extinct:	Where a species is no longer found in its natural habitat, but may be preserved in cultivation.

In today's post-modernist society we may draw sociological maps to identify those persons most interested in the environment and conservation issues. It is clear this is a major concern of a relatively small group in spite of the high profile in the popular press and the media. When we appreciate how small this group of people is, it should act as a springboard energising us to encourage others in our community to broaden their interests and concern for our precious flora.

It has been suggested that when populations of plants or animals fall below a critical number of between 50 to 100 individuals, a genetic crisis occurs. The species is destined for extinction unless direct intervention by people boosts the size of the population in order to ensure that the rate of mutation exceeds the rate of loss of genetic variation.

Further survival of a species or cultivar depends on many factors, including very basic knowledge. Some of this will include details of location and plant numbers to maintain viable gene pools in the wild. However, the ultimate success of any scheme to conserve plants is dependent on propagation and cultural information

which should be recorded systematically.

There has been considerable global interest in our indigenous flora. The value of domesticated plantings should not be underestimated in the preservation of a species. There is a classic story that tells of how *Sophora tomomiro* from Easter Island, following exploitation by the native people, was clawed back from extinction using plant material grown in Europe from seeds collected by Thor Heyerdahl on the Kontiki expedition. In New Zealand we can find similar examples. None would be known better than *Tecomanthe speciosa* where, from only one plant known to exist in the wild, propagation by enthusiasts has made this plant relatively common allowing it to be both widely appreciated and planted.

Even the giants of our forest (*Agathis australis*) require some protection from both our feet and axes. Our forefathers have been no better stewards of our land than the people of Brazil or Sarawak. A head start on forest clearing of perhaps 200 years in New Zealand doesn't make it any more acceptable or right.

How fast our flora develops towards extinction or away from it can be influenced by plant propagators. The future of many plants is in our hands and is our responsibility. At a recent I.P.P.S. conference Bruce Macdonald is reported as saying "native plants may be just as effective as expensively bred hybrids. The University of British Columbia's Botanic Garden Plant Introduction Scheme has released 14 new cultivars, in all over 5 million plants being sold to date (Sept, 1992). Four of these selections are native [to British Columbia] and are becoming increasingly important because of their adaptability for use on widely divergent sites."

From the preservation angle, some of our native plants present a major problem as they flower abundantly every few years, but not every year. The synchrony (with related plants in the northern hemisphere) and flowering of beeches in alternate years has long been known (Poole, 1949). Brockie (1988) reported several indigenous plants including *Phormium* exhibit a marked three year flowering cycle. Inevitably irregular seed supplies cast more dependence on vegetative propagation at the expense of genetic diversity.

The potential genetic resources of the New Zealand flora have been reviewed recently (Harris and Heenan, 1992; Haase, 1990). The horticultural merit of New Zealand native plant cultivars has been recognised internationally by the International Horticultural Congress who have endorsed the Royal New Zealand Institute of Horticulture as the International Registration Authority for *Coprosma*, *Hebe*, *Leptospermum*, *Phormium*, and *Pittosporum*. Examples like these confirm the willingness of plant propagators to select, multiply, and distribute within the nursery industry.

Many selections have been made because they were different, but not necessarily superior to the common form and may represent a complete anathema to the purist. The number of recorded cultivars of New Zealand plants is more than 350 (Metcalf, 1987) and is growing rapidly. This rapid increase in the introduction of new cultivars and variants may have arisen due to any combination of the following factors:

1) Consumer demand for something new at the expense of the simple species that may be too old or "common" for commerce.

2) Nursery people tend to name any variant without proper evaluation of its real merit for cultivation.

3) Plant breeders are becoming more active in working with non-crop plants.

Relatively little information has been documented on the germination requirements of New Zealand native plants (Fountain and Outred, 1991). The paucity of reports on germination requirements of many plants is reflected in the information available in varying detail for less than 5% (113) of all indigenous species. Much of this useful and essential information is already known, but resides only in the heads of experienced propagators, and is destined to be lost unless passed on or written down for future generations of propagators. Plant propagators should endeavour wherever possible to record information about the species they are growing so that the experience gained will not be wasted and require further trials.

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Is Horticulture in New Zealand Environmentally Friendly?

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My occupation has taken me to many countries and allowed me to evaluate excellence in horticulture. I am the guy next door with a family to raise and support and, like you, have suffered the confusion brought about by the missionary zeal of earth guardians.

New Zealand horticulture is not as environmentally friendly as it should be but it could become a world leader in conservation and restoration.

Most New Zealand horticulturists are responsible and concerned but we still need a watch-dog. It may not be sufficient to rely solely on the conscience of fellow growers, as our undoing may come from ignorance, complacency, and greed before irresponsibility.

This industry requires a fully integrated plan for the conservation and restoration of our environment. The sooner we assume responsibility for the stewardship of remaining world resources and acknowledge the follies of the past, the better.

Several past I.P.P.S. papers dealt with related issues such as reusing poly-tunnel covers to planning and operating water recirculation systems. In isolation they only tinker with the issue.

Maybe we see ourselves as beautifiers, part of the solution and not the problem.

We may have to change long held attitudes and instill greater empathy for environmental issues in the younger generation. Through such actions our industry is in a win-win situation.

As an international body of high repute the I.P.P.S. is uniquely placed to call for an environmental code of practice for horticulture. This is no longer a political issue but an inescapable one that will not go away. Although our industry is not likely to be called "dirty" we are not as clean and environmentally friendly as we could be. We must take the initiative before legislation is imposed upon us.

New Zealand is a temperate land of green hills, large stands of forest, fresh water lakes, and fast flowing rivers. It is still young in evolutionary terms—molded by earthquakes, eruptions, fires, and floods. New Zealand's hills are intensively farmed and the forests are mostly man-made exotic stands. It is an under-populated, highly geared agro-forestry ecosystem generating high outputs with high inputs. I do not doubt that if New Zealand bore the population density of many European countries it would be wilting under environmental degradation and abuse.

There are five major environmental concerns pertinent to horticulture world-wide. These are:

1) Fertiliser run-off
2) Chemical residues
3) Chemical hazards
4) Peat extraction
5) Non-degradable packaging

New Zealand has more to lose than most countries. During the post-war years New Zealand's political stability made it a popular haven for offshore investors. Environmental protection leads to bankable business opportunities. Our future fortunes lie in specialty food production and tourism.

New Zealand could be promoted as a haven for pollution fatigued refugees. It has the opportunity to relieve tropical rain forest decimation with its fast growing radiata pines.

Protecting and enhancing our image overseas is the key to the future well-being of the country. We can make or break that image and need to be mindful of the fragile nature of such gifts.

The fertiliser run-off issue and its environmental impact primarily relates to two fertiliser sources—phosphorus and nitrate nitrogen. New Zealand has had a love affair with superphosphate since the arrival of European settlers and sheep. Enthusiasm for the element is now folk legend and has spilled over into horticulture where it is often a nuisance rather than a help.

The economic recession and stock market crash was something of a silver lining. Farmers cut deep into expenditure and fertiliser usage declined. This breathing space should be capitalised on before the next round of excess.

There is the opportunity to select more modern fertiliser technologies (slow release and controlled release formulas) which offer significant reductions in leach losses and more output from less input.

Developments in soilless potting media and water management are contributing to less waste and a harmonious environment. New Zealand can benefit from the experience of other nations and avoid excesses by looking at hydroponics, recirculation, and the like.

THE SWING FROM EXCESS TO PROHIBITION

European and North American growers currently carry the burden of state or federal imposed expenditure on recirculation systems. The pendulum has swung from excess to prohibition which all can be avoided if we act with responsibility and sincerity.

Chemical residues are in food through over zealous use of pest and disease suppressants, eradicants, and growth promotors. Our enthusiasm for quick chemical solutions has resulted in more virulent pest and disease strains which perpetuate the need for more toxic chemical eradicants.

Television brings us many illustrations of chemical disasters and the effect of short term, high level exposure to common agro-chemicals. I doubt that anyone is unaware of the long term consequences of even low level exposure to such materials.

The soil sterilant, methyl-bromide, is still available in New Zealand although banned long ago in Germany following the discovery of residues in lettuce. Australian growers have reported crop losses from routine fungicide applications. This raises the issue of the value of such universally utilised crop management tools.

Chemical crop enhancement can be hazardous for operators. Safe storage and responsible disposal procedures need attention to detail. Hardly a day goes by without some spill or leakage being reported. We suffer a "it will never happen to us" syndrome. The dangers are very real even if not seen.

It would be naive to assume those responsible for chemicals will simply roll-over

and let their empires die. They will not, however, stem the tide of informed public opinion.

Less chemicals and better harnessing of natural predators and bacteria has a lot of appeal. Integrated pest management systems need more encouragement even through legislation.

PEAT EXTRACTION

The hot potato of overseas horticultural environmental issues is that of peat mining.

In the UK anti-peat groups focused on the loss of unique habitat for bog flora and fauna. Research and development into peat alternatives is sufficiently advanced for peat to be consigned to the annals of horticultural history in New Zealand.

We have highly sophisticated processing and composting techniques for radiata pine bark which are proven more reliable and of more consistent quality than harvested peat. We still extract significant quantities of peat, presumably through some perverse loyalty to European tradition or through ignorance.

This year saw the New Zealand Government raise a levy against extracted peat, a small proportion of which goes to the Department of Conservation to fund work. This classic trade-off defies logic. We should tackle the cause not the effect.

RECYCLING PLASTICS

An issue being addressed with speed and vigour in Germany is recycling plastics, especially those used in packaging. German legislation places responsibility in the hands of the manufacturer or packaging businesses. Polystyrene, used for seed and cell trays, is coming under close scrutiny because of its impact on the ozone layer.

Horticulture uses significant amounts of plastic and virtually none is currently recycled. Dirt and soil contamination is a major obstacle. Plant pots are being made from recycled plastics, so why do we export milk containers to Australia for recycling and why do we have plastic milk containers when glass bottles are recyclable?

We need to plan in coordinated fashion and acknowledge New Zealand's inherent and unique advantages.

The horticultural industry unlike those in the U.S.A. or Netherlands, is not concentrated or long established. We may have the time and opportunity to organise effective solutions before less sympathetic or informed parties claim control.

Self regulation is likely to be a better option than imposed legislation.

Agathis australis: A New Era for Kauri Propagation

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INTRODUCTION

Less than 200 years ago there were 1.2 million ha of kauri forests in New Zealand, but today there are only about 4,000 ha left. Kauri forests were extensively clearfelled and cutovers burned by the early settlers until the 1950s. Since then they were selectively logged for approximately 20 years. Today all the larger remaining kauri forests are protected as reserves (Halkett, 1991).

Kauri timber is a superb textbook-grade softwood, highly esteemed by all craftsmen who have ever converted this fine wood into boats, buildings, furniture, musical instruments, etc. Kauri has also been the subject of research and observation since 1885 and there have been over 600 articles written (Ecroyd, 1991 unpublished bibliography). The efforts of the New Zealand Forest Service, the indigenous forestry group at the Forest Research Institute, the Department of Conservation, various New Zealand Universities, and the general public are acknowledged.

A cursory review of past efforts to propagate and grow kauri has revealed that the work to recreate a national resource from this magnificent species has been disappointing, to say the least. Numerous trees have been planted in forests, parks, gardens and on farms—many of which are but a poor reflection of the species. A seed orchard was also established in Waipoua Forest in the 1950s by the New Zealand Forest Service. Of the hundreds of thousands of trees planted over the last one hundred years throughout the country, only two or three small groves appear to be doing well, and a few individual trees could be described as excellent. These *few are of good form and growing at a satisfactory rate.*

Kauri is a large tree. Kairaru, a tree in Tutamoe Forest, contained 735 cubic metres of millable timber, before being destroyed by fire. Tane Mahuta in Waipoua Forest, and Hokianga and Rakaunui in Omahuta Forest, all exceed 50 m in height. Today there are only three remaining trees containing over 200 m^3 of timber in their straight trunks—Tane Mahuta which equals 224.5 m^3, the Phantom which equals approximately 210 m^3, and Te Matua Ngahere which equals 208.1 m^3. These three trees are estimated to be more than 1,000 years old. Fourteen known trees contain over 100 cubic metres of merchantable timber. More could remain unbeknown in Warawara Forest—a forest sufficiently remote and in such wild country that, for the most part, it is unexplored.

Kauri is neither a primary colonising species nor a climax forest tree. It occupies Stages Four and Five in a Six-Stage order of forest succession (Platt, 1987). It is further subject to an order of development: this is the relationship kauri has with other trees of its own species, which draws them up into the magnificent straight trees they are capable of growing into. Kauri is dictated in every aspect of its growth

and development by these two natural orders within the forest structure.

We now know that each of the tree's complex needs must be met before successful forest growth and development is possible. The needs of kauri are:

- Good genetic stock
- Adequate light
- Adequate nutrition
- Correct temperatures
- Correct water availability
- Correct spacing
- Correct thinning during growth of the forest

We believe all the needs of *Agathis australis* have now been identified, allowing us to proceed with trials to ensure that each of these needs is met.

HELICOPTER COLLECTION

Collecting seed and scion wood off giant and remote trees has been so daunting as to be beyond consideration. The simple fact is that if you can climb up a kauri tree, the tree is often inferior as to not warrant further consideration. The idea of using a helicopter to aid in seed and scion wood collection was conceived and debated. Jenny Aitken-Christie, John de Ridder of Marine Helicopters, Keith his assistant, and Graeme Platt commenced a programme to develop the concept of picking kauri material from a helicopter. Flying a Bell Jet Ranger, we visited various forests for collection of material. Suspended in a harness on a long strop under the machine, Graeme was flown to the crowns of many trees, where he was to collect both scion wood and immature cones for propagation by grafting and micropropagation.

As the pilot was unable to see the collector under the machine, a system of hand signals was employed, so that the observer could pass on instructions to the pilot. The concept of using a radio for this work was rejected, on the grounds that the collector was unable to see the helicopter and did not know which way it was facing. Good team work allowed for the pilot to place the collector anywhere within the crown of the tree.

These flights were probably the most important breakthroughs in this project. It established for the first time that quality scion wood and seed could be collected off mature kauri trees, regardless of height or remoteness of location. As a result of these flights, scion wood grafted from several selected mature trees has successfully taken, proving that gene stock can be successfully brought into cultivation from the most elite trees of a thousand years old or more.

TRADITIONAL PROPAGATION

Kauri is traditionally grown from fresh seed, which must be planted out within three months of picking. Poor germination or no germination will result from seed that is old. Seedlings will reach 0.75 to 1.2 m in 3 years. To facilitate calculations on kauri growth and performance, we have given all kauris a birthday on March 1st. This date was arrived at because seed is ripe in the last week of February and the first week of March, and as it must be sown fresh that date is very relevant in the life of kauri. Furthermore, most growth for the year will have been completed by March 1st—therefore any measurements will not change until the following

September. This arrangement has proved to be very satisfactory. The fastest proven growth rate for kauri is 2.9 m in 3 years, from a young tree growing at Driving Creek, Coromandel; and the slowest is 1 m in 30 years for a tree in Tairua.

Grafting a kauri from ancient trees has proved to be a rather frustrating operation. It is fair to say that all the collections have been done at the most unsatisfactory time of the year, and that grafting should be carried out during early to mid-September as reported earlier (Thulin, 1957). However, flights into the forest have always been organised during the spring (November) and the first week of March, to collect both seed and scion wood for the laboratory. Therefore, to date grafting has only been done as a secondary operation.

Successful grafting of giant trees is a major breakthrough in conservation. It means that our superior gene stock can now be brought into cultivation and preserved in perpetuity in gene banks and seed orchards. It is known that *A. australis* can be cutting propagated from young trees, and it is eventually hoped that grafted scions will provide quality material for cutting production.

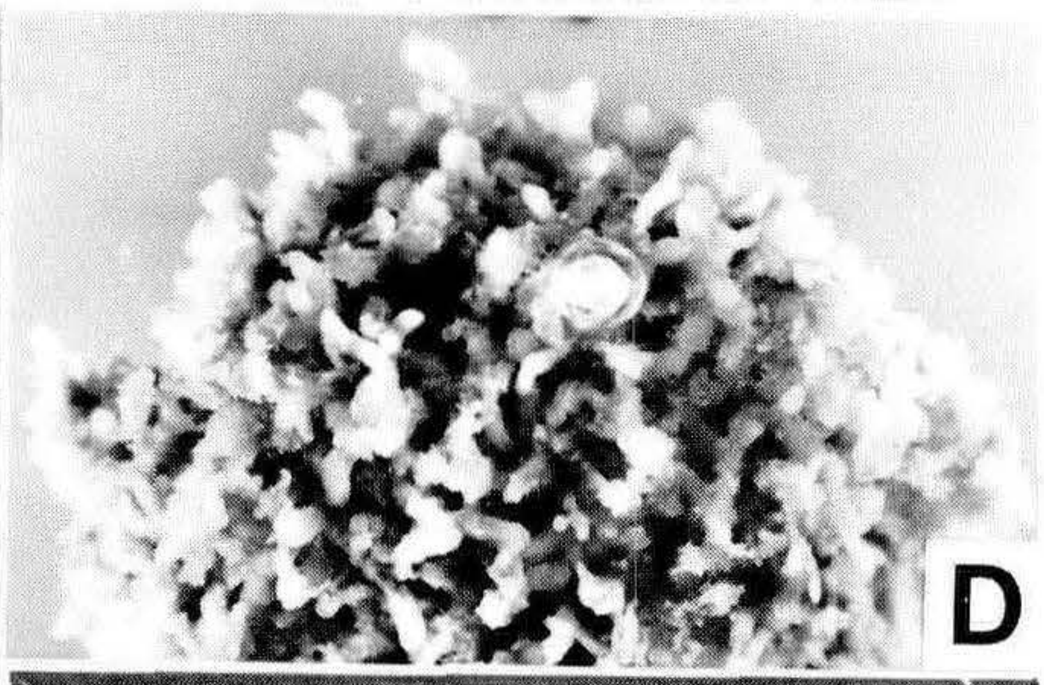
MICROPROPAGATION

Micropropagation and somatic embryogenesis methods are currently being developed using a variety of selected juvenile and mature explants by Keiko Gough, Helen Davies, Lyn Holland, Susan van der Maas, and Jenny Aitken-Christie of the New Zealand Forest Research Institute.

Micropropagation of Selected Juvenile Trees. Seven 3-year-old kauri trees were selected on the basis of form, growth rate, leaf shape and size, and apical dominance from thousands of seedlings. For the micropropagation of these juvenile select trees a reliable method for sterilisation of shoots has been developed. Preliminary success with shoot growth and multiplication has been obtained but it is by no means optimal. There are currently more than 600 shoots from seven clones, either in culture or in soil, and rooting experiments are underway. Some plantlets have been produced and are growing in the glasshouse. Methods need to be optimised further to increase multiplication rates and to obtain reliable rooting. Growing-on plantlets for field and clonal testing will take several years. New selections will be incorporated into the programme to increase the number of clones when they become available. Similar results have been obtained in the micropropagation of other Araucariaceae species (Burrows et al., 1988; Sehgal et al., 1991).

Micropropagation of Selected Mature Trees. Mature kauri shoots were collected by helicopter, as described, or by using long-reach pruning shears and subsequently placed into culture. The overall success rate was less than 10%. Contamination, poor nutritional status, and age of the material were the main reasons for losses. Despite high losses, healthy growing shoot cultures from mature kauri more than 500 years old have been established for some collected clones.

Shoots from grafted mature select trees have recently provided better material for micropropagation. Grafted kauris were placed in the glasshouse, where fertiliser, fungicide, and insecticide were applied. New shoots were collected, sterilised, and placed into culture. Approximately 80% of these shoots survived and grew on. The growth of mature shoots in culture is much slower than juvenile shoots. No shoots have been rooted yet.



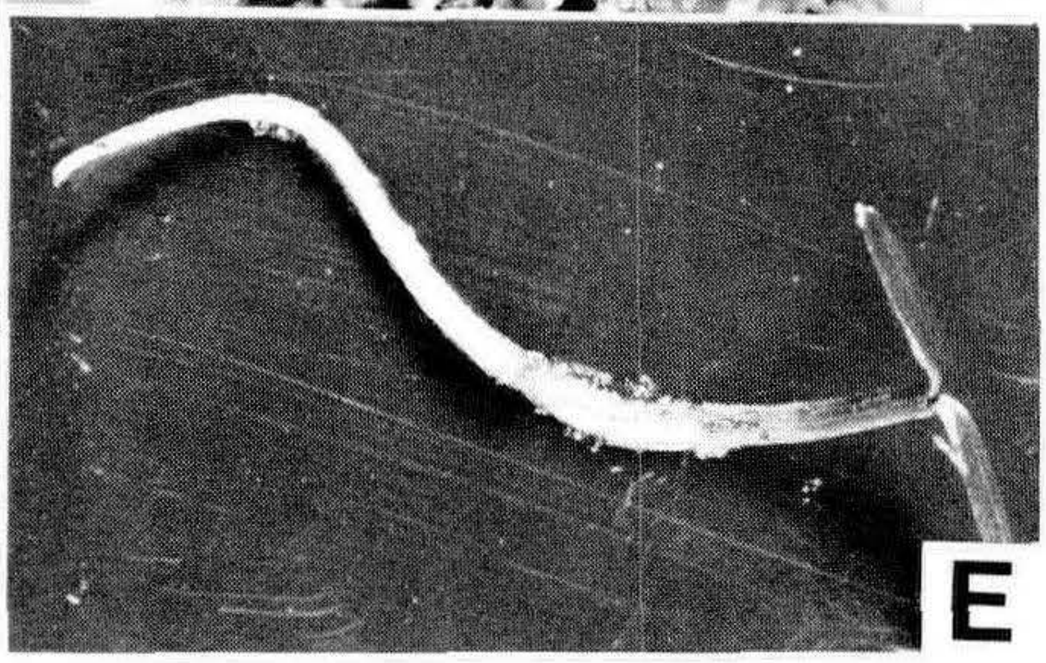


Figure 1. Collection and propagation of *Agathis australis* (kauri): (A) Giant kauri tree more than 1,000 years old; (B) Collection of material from upper crown of tree by helicopter; (C) Grafted kauri plant approximately 1 year after grafting; (D) Embryogenic tissue formed in culture from immature kauri seed; (E) Somatic embryo with well developed cotyledons and root.

Embryogenesis. There has been a very high success rate in the initiation and proliferation of embryogenic tissue of kauri using immature seed tissue from 2-year-old cones collected by helicopter. Somatic embryogenesis in conifers was previously described by Jones (1990). There are 631 embryogenic cell lines (clones) in culture and more than 8,000 embryogenic calli. Each callus can produce approximately 10,000 embryos. Over a thousand mature somatic embryos have

developed on media containing abscisic acid (ABA) and embryos with well developed cotyledons, hypocotyl, and radicle have been formed. Further work on embryo germination and transfer to soil needs to be done to complete method development. Preliminary experiments have shown that somatic embryos germinated better on sterile gelled medium than in soil. This is the first report of embryogenesis for any species in the *Araucariaceae* family.

Formation of white, translucent embryogenic-like tissue from 1-year-old unfertilised cone tissue from superior mature trees has also been achieved. This is a major breakthrough in conifer tissue culture and could lead to the production of rejuvenated plantlets that would be genetically identical to the parent tree. DNA/chromosome analysis and microscopic examination of the origin of the tissue will confirm if rejuvenation has occurred. Collections and culturing of cone tissue during 1991 and 1992 have led to the establishment of 550 clonal cell lines. Further research to prove that these cell lines are embryogenic and that mature embryos can be developed from them is necessary.

Anatomical studies on the origin and development of kauri embryogenic tissue and somatic embryos from both 1- and 2-year-old cones compared with natural embryos are also being carried out in collaboration with Professor John Owens and Glenda Catalano of the University of Victoria, Canada, as is a full study on pollination, fertilisation, cone development, and cytoplasmic inheritance.

When sufficient micropropagules have been produced via either organogenesis or embryogenesis, field trials will be conducted along with seedlings of similar genetic origin.

CONCLUSIONS

Our understanding of the requirements for optimal growth of kauri in the forest has advanced during several years of research. New technology using micropropagation techniques is now being developed for propagating superior trees and preliminary results are encouraging. Consequently, a re-evaluation of kauri forestry is underway, with the objective of producing a crop rotation of 50 to 60 years. Conservation of germplasm of one of New Zealand's most valuable native trees is also an objective.

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Cryopreservation of *Pinus radiata* Embryogenic Tissue

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Five *Pinus radiata* embryogenic cell lines were successfully recovered following storage in liquid nitrogen for periods of up to nine weeks. Sorbitol and DMSO were used as the cryoprotectants, and a simple protocol using a -30°C freezer as an intermediate step was used. Nurse cultures using established embryogenic cell lines facilitated rapid post-thaw recovery. Cryopreservation of *P. radiata* offers a new tree-improvement tool, as clones from superior families may be maintained in a vigorous juvenile phase while clonal field trials are carried out.

INTRODUCTION

Plantation forestry covers 1.2 million hectares of land in New Zealand, 89% of which is *Pinus radiata* D. Don. Forestry products accounted for 9.5% of New Zealand's total exports in 1990 and this figure is predicted to increase to perhaps 30% by the year 2010 (Ministry of Forestry Official Statistics, 1990).

Annually, 40,500 ha of forest is established (Forestry Facts and Figures, 1992) and/or restocked from seedlings grown from seed in nurseries. A small portion of planting stock is from cutting material taken from trees less than 5 years old. Most seeds are produced from commercial seed-orchards. Orchard trees are selected for commercially desirable traits such as growth rate, stem straightness, freedom from major defects, and disease resistance. Radiata pine has many different end uses with traits such as those listed being required by most users. Tree breeders manipulate these and other traits, like wood density and branching habit, to produce seed lots that meet the specific requirements of their clients (What's New in Forest Research No. 182, 1990).

Pinus radiata exhibits maturation characteristics with age. The overall growth rate slows, dormant buds form at shoot tips, and male and female cones start to develop. Due to these characteristics, cuttings taken after about age four show significantly slower growth rates than seedlings, which reduces the potential advantages of using them (Menzies et al., 1991)

Various processes are available which enable scarce control-pollinated seed to be "vegetatively amplified" to make planting stock available over a larger area. A seed may be used to produce a stool bed from which cuttings may be taken for setting directly in the nursery bed (Menzies et al., 1985). This operation has a reasonably low cost, but the multiplication rates are low.

Commercial-scale micropropagation (tissue culture) technology has been developed to vegetatively amplify limited numbers of seeds (Nairn, 1992). The micropropagation option is more expensive to set up than a cutting option, and the planting stock produced is three to seven times as expensive as seedlings (Smith, 1986). However, some genotypes may be cool-stored at 4 to 10°C (Smith et al., 1982; Aitken-Christie and Singh, 1987) while clonal material is field tested. The stored

material may retain its juvenile state (this has yet to be fully tested), and would circumvent the problems of maturation in clones grown in the field. Thus it may be possible to return to a collection of stored juvenile material to provide a source of tested clones within superior seed families.

One potential problem with cool storage is that the tissue is still physiologically active at 4 to 10°C. It is necessary to return material to room temperature and to transfer to fresh medium at intervals of between six months and two years, following which the material is cool-stored once more. Not all genotypes tolerate this treatment, and some are lost during storage. Since the physiological processes in material stored at 4 to 10°C are not totally suspended, some physiological and maturational changes may be expected, especially when storage for up to eight years is required.

Cryopreservation, the storage of tissues in liquid nitrogen at -196°C, has been used for many years to preserve animal semen. In recent years, cryopreserved animal embryos have developed into viable animals when placed into a receptive womb. Plant tissue presents some difficulties as most plant cells contain small vacuoles that contribute to tissue damage during freezing and thawing. Whole plant organs are difficult to cryopreserve. However, embryogenic tissue is readily preserved due to the absence of vacuoles in the proliferative tissue.

Somatic embryogenesis in a conifer was first achieved with *Picea abies* (Hakman et al., 1985), and since then with other species including *Pinus radiata* (Jones, 1990; Smith et al., 1991). Successful plant formation after cryopreservation of coniferous embryogenic tissue has been reported with *Picea glauca* (Kartha et al., 1987), *Picea mariana* and *Larix* ×*eurolepis* [=*L.* ×*marschlinsii* Coaz.] (Klimaszewska et al., 1992), and *Pinus caribaea* (Laine et al., 1992).

As with other plant species, four components of the cryopreservation process contribute to success:

1) **State of the tissue:** Embryogenic tissue should be in a vigorous growth phase, with a high density of embryo initials that have no vacuoles.

2) **Freezing of tissue:** The non-permeating compound sorbitol and the permeating compound dimethylsulphoxide or similar "cryoprotectants" should be used to minimise tissue damage during the first freezing stage to -30°C. Although both of these have both proved to be cytotoxic at high concentrations (Chen and Kartha, 1988), they are useful for coniferous tissue.

3) **Thawing of tissue:** Embryogenic tissue should be thawed relatively quickly, effectively done by plunging cryopreservation vials into water at 40°C.

4) **Growing-on tissue:** After thawing, tissue should be rinsed to remove cryoprotectants, and then cultured on media suitable for cells at low density.

GENERAL METHODS FOR CRYOPRESERVATION OF *PINUS RADIATA* EMBRYOGENIC TISSUE

Embryogenic Tissue Pretreatment. Embryogenic tissue was removed from a maintenance medium and suspended in liquid embryogenesis medium (EM) with 73 g/l sorbitol at a ratio of 1 g fresh weight to 3 ml of EM (embryogenesis medium was developed at the Forest Research Institute). The suspension was pipetted into 25 ml flasks which were stoppered with a cotton bung and then covered by

aluminum foil to prevent contamination. Flasks were incubated at 24°C on an orbital shaker (50 rev/min) for 12 to 48 h.

Freezing. For cryopreservation, 0.5 ml of suspended tissue was transferred to 1.8 ml cryovials (Nunc). Cryovials and 20% dimethylsulphoxide (DMSO) were held on ice to equilibrate, and 0.5 ml of DMSO solution was added to the 0.5 ml of suspension to give a final concentration of 10% DMSO. In preliminary experiments, a final concentration of 5% DMSO was used. Vials were put into aluminum tubes called canes and transported in ice to a -30°C freezer. Canes were placed in the freezer for 2 h to freeze the suspension then put directly into liquid nitrogen (-196°C). The liquid nitrogen was held in a dewar and kept in a cool room (4°C). Regular checks were made of the liquid nitrogen levels to ensure samples remained fully immersed. Embryogenic tissue was held at -196°C for up to 9 weeks.

Thawing. To reinstate growth, vials (up to 5 at one time) were removed from a cane and immersed in 40°C water until the frozen suspension plug dissolved. This took no more than 2 minutes. Vial contents were then poured, one at a time, onto a nylon screen in a millipore filter unit (Fig. 1). Rinsing medium was poured over the sample which was centred in the nylon screen by the use of autoclavable plastic washers. The contents of each vial was rinsed with 100 ml of rinsing medium (EM + 30 g/l sucrose). One millipore unit was used for 15 vials before being replaced with

Figure 1. Thawed samples are poured onto a nylon screen in a millipore filter unit.

a new sterile unit. Washings were sucked into a receiver bottle on a vacuum line. The nylon screen with embryogenic tissue was put onto initiation medium for one week in experiment 1, and for 2 h in experiment 2 (Fig. 2). After 2 h or 1 week, the nylon screen and tissue were transferred to maintenance medium, embryo-development medium, or onto fresh embryogenic tissue that then served as a "nurse" culture. Nurse tissue was separated from the thawed embryogenic tissue by a 30-micrometer-pore nylon screen. A nurse culture consists of an actively growing mass of embryogenic tissue in direct contact with a nutrient medium.

Survival Assessment. The fresh weight of regrown tissues was recorded at completion of experiments.

Early observations of thawed embryogenic tissue were made using a stereo microscope. Embryogenic tissue was stained with acetocarmine, to determine cell survival.

RESULTS AND DISCUSSION

Experiment 1. The period of storage in liquid nitrogen was evaluated in this experiment. At -196°C, cells are metabolically inactive and duration of storage should not affect subsequent regrowth. Five cell lines were tested; two (M-31 and M-33) shared the same parent trees (full sibs) and the other three cell lines are

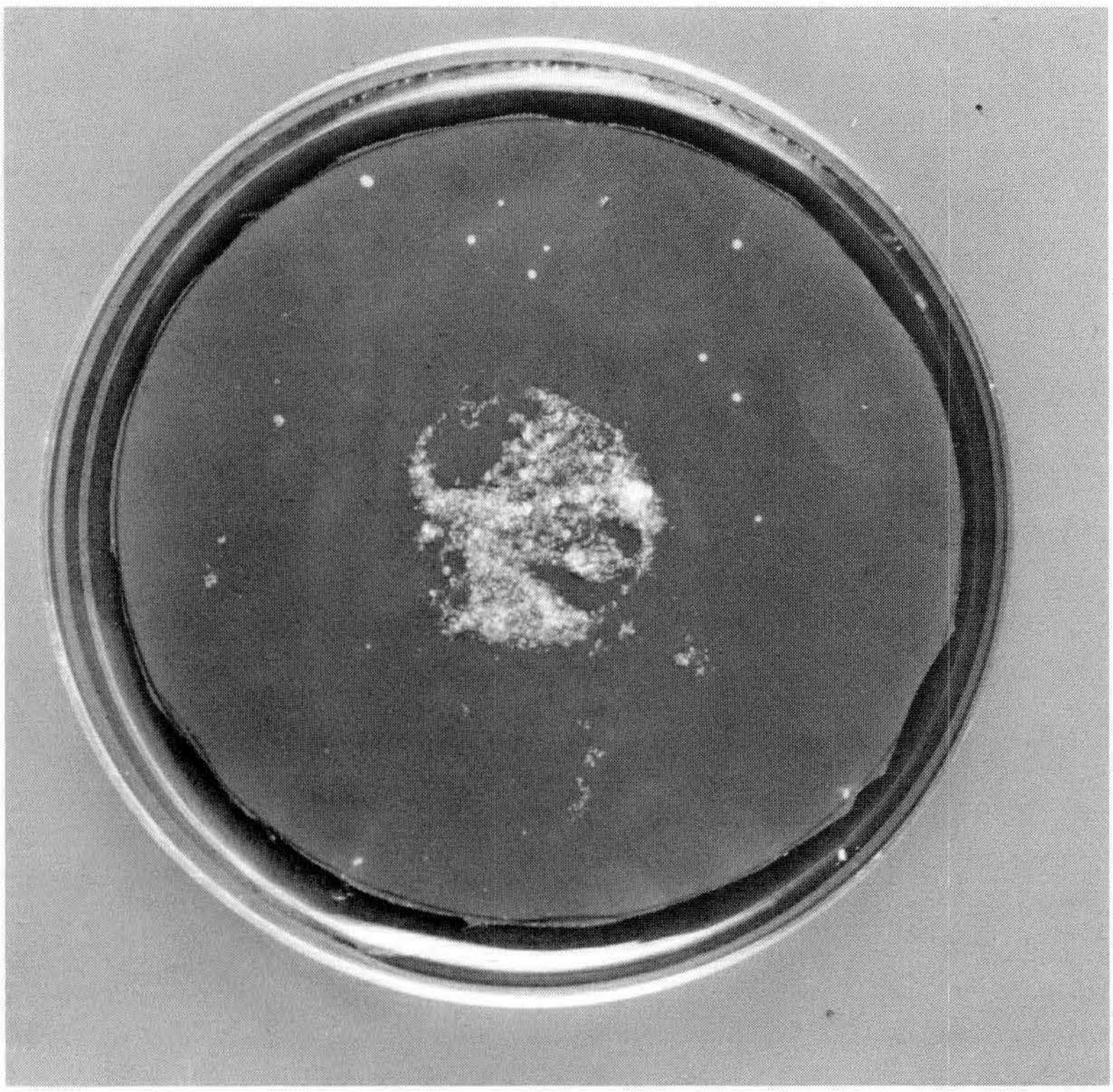

Figure 2. Nylon screen with rinsed embryogenic tissue on initiation medium.

unrelated. Three cell lines were white (76-2, 191-8, and M-33), while K-18 and M-31 were brown in colour, a characteristic of some embryogenic cell lines. Six vials of each cell line were frozen on day 0 of the experiment, and two vials were removed at each time period. Fresh weight of tissue per vial was 0.166 g.

Table 1 shows the fresh weight of embryogenic tissue 16 to 20 weeks after thawing from liquid nitrogen (LN). Each treatment had two replications of each cell line.

Table 1. Fresh weight (g) of tissue after regrowth on maintenance medium.

Time in liquid nitrogen	24 hours		1 week		1 month	
Weeks on maintenance culture	20		19		16	
Replication	1	2	1	2	1	2
Cell line						
76-2	6.87	1.79	0.05	0.03	1.52	0.04
M-31	0.06	0.04	0.07	0.06	0.07	0.08
191-8	9.73	6.97	5.64	9.36	3.85	6.00
M-33	2.31	3.14	0.06	11.73	0.05	0.06
K-18	0.03	0.05	0.05	0.06	0.05	0.04

Cell lines M-31 and K-18 did not survive immersion in liquid nitrogen. Cell line M-33 showed regrowth after storage in liquid nitrogen for 24 h and 1 week.

Cell line 76-2 showed no survival after 1 week in liquid nitrogen, but after 1 month in liquid nitrogen, replication one survived. Cell line 191-8 was unaffected by the storage period in liquid nitrogen and all replications grew well on maintenance medium.

The lack of survival in cell lines K-18 and M-31 may be attributed to their growth state before cryopreservation. They were both brown in colour, possibly indicating a lack of vigour. Laine et al. (1992) emphasised that for the optimal recovery of viable cells from *Pinus caribaea*, embryogenic cell suspensions must be vigorous. When they used suitable cell suspensions, it was possible to achieve 100% recovery of cryopreserved samples. If non- or poorly-embryogenic cultures were cryopreserved, it was difficult to obtain any regrowth after thawing.

Pinus radiata embryogenic tissue that did not grow after thawing showed loss of fresh weight. This weight loss was due largely to the collapse of highly vacuolated suspensor cells that make up most of the tissue bulk on maintenance medium, and had become plasmolysed during the pre-freezing incubation step.

Experiment 2. For Experiment 2, there were 10 vials each of unrelated cell lines F92-2 and Q92-1, which were frozen and subsequently thawed after 9 weeks storage in liquid nitrogen. Fresh weight of tissue per vial was 0.166 g. Two treatments were used; after 2 h on initiation medium, rinsed tissue was either placed directly onto embryo development (ED) medium or onto a nurse culture on ED medium. Tissue was weighed nine weeks after thawing.

Table 2. Fresh weight (g) of cryopreserved tissues directly on agar medium or on nurse tissue, after nine weeks of culture.

Cell line	F92-2		Q92-1	
Replication	Directly on medium	Nurse tissue	Directly on medium	Nurse tissue
1	0.04	contaminated	0.04	3.08
2	0.04	0.72	0.06	1.38
3	0.04	0.47	0.08	1.73
4	0.04	0.92	0.05	contaminated
5	0.04	0.61	0.04	4.73
Average	0.04	0.68	0.05	2.73

The nurse culture ensured survival and growth of all replications, while the tissue placed directly on embryo development medium did not grow. Cells on the nurse treatment when stained with acetocarmine were bright red and had dense cytoplasm. The tissue placed directly on embryo development medium showed extensive cytoplasmic damage.

The positive effect of the nurse culture may be attributed to the benefit of growth promoting substances released by the actively growing cells. It is also possible that the mass of nurse cells absorb cryoprotectants or toxic metabolic products from damaged cells after thawing.

CONCLUSIONS

In these two preliminary experiments, five unrelated *P. radiata* embryogenic cell lines have survived immersion in liquid nitrogen for periods of 1 day to 9 weeks. Post-thawing growth is enhanced by the use of a nurse-tissue treatment.

These preliminary experiments indicate that *P. radiata* embryogenic tissue can be cryopreserved without recourse to sophisticated programmable freezing equipment. It is reasonable to expect that storage for longer periods than 9 weeks in liquid nitrogen should be possible. Long-term storage of tissue should allow the field testing of clones within superior families. When phenotypes with useful industrial properties are identified, tissue from the same clone can be recovered from cryopreserved foundation stocks. Since the cryopreserved tissue will still be in the embryogenic state, it will serve as a source of vigorous, juvenile planting stock. Thus, truly juvenile donors of tested clones will be available, and it will finally be possible to circumvent the problem of maturation which has been identified as an impediment to clonal forestry (Sweet and Wells, 1974).

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Is Green Good Enough?

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The accepted standard for evaluating plants has been color. If a plant had "good green color," it was assumed to be healthy and as good as one could expect. Basic nursery practices reflect this assumption. Unless some yellowing or lightening of the green color occurred, little, if any attention was given to refinements in nutrition. As one nurseryman said, "My goal is to keep the plants green."

Research over the years has convinced me we can do much more to enhance plant health. Following is a compilation of some of these experiments and my comments on what they mean for the future.

In 1975 I compared several rates of each of several micronutrient fertilizers with supplements of specific elements. Midway through the growing season a heavy grasshopper population developed. I considered spraying for the grasshoppers; however, we had no appropriate insecticide on hand, and by the time the pesticide arrived, I noticed an interesting trend. The grasshoppers were not feeding on the Burford holly plants indiscriminately. Leaf damage was slight to the chlorotic control that had no micronutrients in the mix and to the two treatments that were much higher in micronutrients and were producing the best growth. The greatest feeding occurred on plants from treatments that resulted in moderate growth and an acceptable green color.

The grasshopper feeding was left unchecked, and the contrast continued to increase. Entomologists were skeptical until they visited the study, which was set up in six randomized blocks.

Burford holly was also used in a study with a number of rates and sources of N, P, and K at the same time. This study was located approximately 40 ft away but on the same container bed. Soil mix, watering, light intensity, and other conditions were the same for both studies. The feeding of the grasshoppers on this study was independent of the N-P-K treatments. However, this study was closer to a large landscape planting of euonymus, which was a favorite target for grasshoppers. To determine if location played a role, three replications of each of the two studies were carefully marked and switched, block for block, the grasshoppers continued to avoid certain micronutrient treatments and to feed selectively on others (unpublished data).

Following this experience I intensified my study of micronutrient nutrition and the influence on plant health and natural resistance. One of the products of that research is Micromax micronutrient fertilizer (Grace-Sierra), first introduced in 1980 (Whitcomb et al., 1981). Various studies followed and continued to show that the natural resistance in plants could be enhanced beyond the visual criterion of being good green color.

By 1988 many improvements in N-P-K slow-release fertilizers and calcium and magnesium nutrition had occurred. Since changes in these five major elements might influence micronutrients, it was decided to investigate further the interactions and rates of six micronutrients. Years of experimental data were reviewed to determine the preferred level for iron, manganese, copper, boron, zinc and molyb-

denum. Treatments in the study were the preferred level, one-half the preferred level, and twice the preferred level. The study was conducted as a 1/9 fraction of a 3^6 factorial (81 treatments) with six replications per species and four species for a total of 1933 plants. The test species were Fashion azalea, dwarf pittosporum, Blue Pacific shore juniper, and Wilson's yellow daylily.

The study was conducted at a container nursery in central Florida in full sun using overhead sprinkler irrigation and trade 1-gal containers (160 cubic in.). The irrigation water was analyzed for chemical content and the level of dolomite adjusted accordingly (Whitcomb, 1988; Whitcomb, 1989).

An experimental 16-5-11 Osmocote formulation was used for the N-P-K. Studies conducted on this same site in 1987 showed this outperformed other formulations and competitive products. Two pounds dolomite and 12 lb Osmocote per cubic yard were added to the soil mix for all treatments. For accuracy, chemicals for each container were weighed out in advance in small zip-lock plastic bags.

The procedure in setting up the study was as follows: Containers were filled with a mix of 3 pine bark : 1 peat : 1 sand (by volume) with no chemical additives. A container of mix was emptied into a 3-gal bucket, the contents of the bag were added and thoroughly mixed by hand, then all returned to the container and labeled. Uniform liners of each species were selected and planted. The study was in place on 24 February 1988. Watering, weeding, and herbicide applications were done as a regular part of the nursery operations. No insecticides or fungicides were used. The entire study was evaluated in June and September, and three of the four species were evaluated in November. In addition, the staff of the nursery monitored plant growth and watched for any outbreak of pests or disease. None occurred.

None of the plants of any of the species showed any chlorosis or discoloration to suggest nutrient stress. Since each plant had at least one-half of what previous studies indicated as the preferred level of each micronutrient element, the total absence of chlorosis was not particularly surprising. What was surprising was the differences in plant growth and quality. The most striking result occurred with Fashion azaleas. The size of the tops of the plants varied moderately when evaluated in November. A difference in the number of flower buds and size of the flower buds could be observed, but no attempt was made to count buds at this time. The decision was made to leave the azaleas and try to evaluate flowering the following February or March.

Wilson's yellow daylily was included at the nursery owner's request. He said that on average single fans planted in one-gal containers multiplied to about three fans at the end of the growing season. In November three of the treatments in the study averaged 7.8 shoots for the six replications, whereas the poorest treatment averaged only 2.1.

Fresh top weights of Blue Pacific shore juniper and dwarf pittosporum were significantly different among the various treatments. Weight of junipers ranged from 95 to 128 g; dwarf pittosporum from 72 to 139 g. However, plant quality varied much more. The juniper ranged from a visual grade of 6.4 to 9.8 on a 1 to 10 scale where 10 is best. The pittosporum ranged from 5.1 to 9.1. The plants were never pruned; however, the number of branches per plant were widely different. For example, the best treatment for the juniper had 66 branches per plant while the poorest treatment hand only 14. This shows that natural branching can be enhanced, which would minimize the need for pruning.

On 25 February 1989, the azaleas were in full bloom. Differences in numbers of flowers were easy to see. It was found that these differences were consistent among the replications. The plants with the fewest blooms per plants averaged only 24 while three treatments averaged 171, 167, and 166. In these three treatments the foliage was masked by the flowers. When the data were analyzed and compared, the same three treatments were best for all four species.

Several observations seem relevant:

1) All 1944 plants were dark green throughout the study, yet substantial differences in plant responses were observed.

2) When N, P, K, Ca, and Mg are in the preferred range, response to micronutrients can be striking.

3) All four species grew most favorably with the same treatments. This suggests that these diverse species have common nutritional requirements and that special container mixes and nutrition programs are not necessary for each species.

4) There were no disease or insect problems on any of the species.

5) Green is not good enough.

The results of this and other studies indicate that plant growth and health can be enhanced beyond just good green color when evaluated by criteria other than color. In this case the criteria were daylily multiplication, azalea flower number, and juniper and holly branching and top weight.

In addition to direct plant improvement, increased branching could reduce the amount of pruning needed. Less pruning would reduce production costs as well as reduce the number of entrance opportunities for pathogens. One of the current challenges is to find a way to evaluate plant health without relying on color.

Consider ranking plant health on a scale from one to 10 where 10 is the best, and below 3 the plant is not a good green.

Unfortunately, at the present time there is no way to tell a plant that would rate 4 from one that would rate 6 or 9. Such a tool is needed if we are to further advance plant health and productivity and minimize labor and our dependence on pesticides.

Green is clearly not good enough. Taking plant nutrition and health to a higher level requires careful evaluation of as many factors as possible that affect plant growth. All of these must be synchronized if plant growth and vigor are to be enhanced. The answers are complex and difficult to sort out, but clearly they are valuable benefits to be had in the future as a result of complex studies nutritional refinements.

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Container Tree Production at Trail Ridge Nursery

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Trail Ridge Nursery is in northeast Florida about 45 miles southwest of Jacksonville. We grow trees in 1- to 30-gal containers. We had originally intended to grow only up to the 15-gal size, but many municipalities are now requiring a minimum caliper of 2 to 2½ in., and we are not able to grow a tree of that size in a 15-gal container.

We have 4½ acres of bed space under overhead irrigation and 5 acres under low-volume irrigation. Our sales are primarily to other nurseries who intend to grow the tree to a larger size and to landscapers.

PROPAGATION

We propagate most of our own trees either from seed or cuttings. We feel that by doing this we have better control of our final product. Whenever possible we collect the seed from local trees and keep a record of the performance from each parent tree. This is especially important with oaks since you can get a high degree of variability.

Another advantage of growing our own liners is that we have more control of the root system. Whether we start the trees in a standard 2¼-in. rose pot, bottomless container, or Dr. Whitcomb's 'Rootmaker'[1], we can pot up to the next container size before we get into trouble from a circling root system.

With seedlings we are able to grow enough excess plants to be able to select the most vigorous plants for potting up. This reduces the number of inferior trees we must cull after they have been potted into large containers.

We like to pot up liners into 1- to 2-gal containers as soon as the roots will hold a root ball. In cases where the root system is more developed, we break up the root system when potting. Unless we break up the root system at each stage of transplanting, the trees wobble in the containers as they get larger due to a constricted root system earlier.

We grow our 1- and 2-gal containers can to can. We once grew only the 1-gal size but found for some trees the 2-gal container allows extra space between the trees and allows those trees to support themselves rather than lean on each other. The trees develop better trunks when they grow without support.

STAKING

We try to do a minimum of staking throughout our production. I personally don't like to see a stake on a tree because staked trees tend to develop trunks that won't support the top. Some trees, however, require staking at one or more stages of production in order to develop a straight trunk.*Salix babylonica, Cercis canadensis*, *Eucalyptus cinerea, Ulmus parvifolia* 'Drake,' and some *Ilex* species fall in that category. Other species only require a stake on an occasional tree. Examples of this are *Quercus virginiana* and *Cornus florida*.

PRUNING

I feel that the most important pruning of our trees is in the early stages of production. A few months after potting up, when the trees have started to grow, we walk though the beds and prune as necessary. We trim terminals to maintain a single central leader, tip the lateral branches that are growing too vigorously, and remove any lateral branches that are becoming dominant. Usually these are branches that are more than half the diameter of the main trunk where they are attached. When we have a tree that can't be straightened with this pruning method, we stake it. I believe in removing as little top growth as possible in order to produce a better root system.

Each species is different, but we repeat this procedure as necessary. For *C. florida,* usually twice is enough. We prune *Q. virginiana* and *Q. laurifolia* about every 4 to 5 weeks. This might seem like a lot of effort; however, after the initial pruning it takes very little time once the pruner is experienced.

SPACING AND TREE SUPPORT

We like to space our trees as soon as we have room for them. Most of our 3- and 7-gal trees are grown on 2-ft spacing. Our tree support system consists of four 12-gauge wires attached on each end to a 4-ft treated 2 × 4 supported by two treated fence posts. In the ground we attach a treated 1- × 6-in. batter board between the post on the bed side and just below the soil line. At the bottom of each post we nail a scrap piece of board on the opposite side of the post. The top and bottom boards stabilize the posts considerably and eliminate the need for guy wires. The beds are 50 ft wide. In order to prevent the wires from giving in a heavy wind we run a chain down the center of the bed for the length of the bed. The chain is attached to each wire with a hog ring and is supported with treated 4-× 4-inch posts every 40 ft. This does a good job of stabilizing the wire. The trees are attached to the wire with a device called a TrellisLok[2]. This is a plastic device that attaches to the wire with a plastic nut and attaches around the tree trunk with a strap that works much like an electric wire strap except that it is reusable.

Our support system for larger trees is similar but built with heavier material. We use 8-ft, 4- × 6-in. treated posts placed 3 ft in the ground. The top batter board is a 2-× 10-inch nailed across the posts just below the soil line. At the bottom of the post on the opposite side we nail a 1-ft piece of 2- × 10-in. board. Each bed is four posts wide; the posts are spaced every 40 ft in the row. We use 3/16-in. aircraft cable to support the trees and also our black polyethylene irrigation line. The cable is attached to each post rather than having one long run the length of the bed. This puts much less total stress on the cable. Trees are spaced either 3 ft or 4 ft on center depending on the individual tree's growth characteristic.

We use low-volume irrigation. A 3/4-inch black polyethylene line starts at the center of the bed and runs to either end. It is attached to the cable with plastic rings. At each pot we drop a length of spaghetti tube to a Roberts Spitter Stake. The trees are attached to the cable with a device called a Dickinson Tree Clamp[3]. It is a plastic device much like an oversized TrellisLok except that it uses a large O-ring instead of a strap to wrap around the tree. We prune the larger trees primarily by limbing up the trunks to get the desired amount of clear trunk, tipping lateral branches to develop a full crown, and removing problem crotches.

CONCLUSION

We attempt to fit in all production procedures at the optimum time. However, like most nurseries we seldom get all stages completed exactly when we would like. We feel strongly that the key to growing a quality tree is early selection of superior trees in the production process, timely pruning and spacing, and a minimal amount of staking.

[1] Lacebark, Inc., P.O. Box 2383, Stillwater, OK 74076
[2] TrellisLok, AgFast Corporation, 1617 S. California, Monrovia, CA 91016
[3] Dickinson Nursery Products, 4044 24th Avenue East, Palmetto, FL 34221

The "Benlate Syndrome" and What To Look For

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There is an epidemic in the ornamental horticulture industry just as real as any health crisis. It's just as real as the AIDS epidemic.

For the past three years, plants have been exhibiting a variety of abnormalities that have been described by researchers and Florida's Division of Plants Industry as the "Benlate Syndrome." The cause of the problem is elusive and baffling. The number of explanations is as varied as the people expressing views. Countless hours are being spent trying to find the cause and to develop mitigation techniques, so far without any real success. All concerned agree that there are plant abnormalities and that the impact is widespread.

The symptoms of the syndrome are lack of plant growth; failure to flower or if they do flower, failure of fruit or seeds to mature properly; distortion of foliage shape and color; chlorosis; cabbage-head growth; lack of sturdiness of plant stems; club-like growth of root tips; dead areas in roots behind healthy tips; excessive proliferation of roots, root growth toward the top of soil surfaces; and a lack of insect population.

In identifying the Benlate syndrome, it is important to look for patterns of symptoms and repetition of these patterns. The symptoms are often subtle. Every plant dose not show all the signs, and each species may show the symptoms a little differently. Definitely, there is a difference in the reaction of monocots and dicots. In dicots, the root symptoms are very pronounced. For example, Indian hawthorn may look healthy and have reasonable symmetry and good color. Plants in my nursery were fertilized the week of April 1st with a 12-week fertilizer. No apparent growth of the shoots has occurred nor has there been any other noticeable change in appearance since April.

When you look at the roots, the reason for lack of growth is apparent. It is not uncommon to find the roots breaking the soil surface and growing into the air. Often, the roots grow toward the top of the container.

On close examination of the roots, several other abnormalities are evident. The tips are large and brittle and snap off easily. Behind the tips, the size of the root diminishes—leaving the appearance of a club head. Often dead areas occur in the middle of the root. Tips on the damaged roots remain white and the area behind the dead spot continues to appear healthy.

The immediate reaction when you see the dead areas is root fungus. However, many times new roots are seen growing from the dead area. In samples I have sent to labs, root pathogens always have been described as secondary in nature. It appears only the phloem is damaged initially. However, after several weeks, pathogens often invade the rest of the root.

Fruiting and flowering also are adversely affected. Many plants just fail to flower. Feijoa, pittosporum, and *Viburnum suspensum* have consistently failed to produce some flowers. These species have always produced some flowers in the nursery. The plants have shown very little growth in the past six months.

Plants that do flower often do not produce mature fruit. We failed to produce a significant number of cucumbers of normal shape and size in our test blocks. While

there are many environmental factors affecting cucumber pollination, we had a half dozen normal cucumbers out of a harvest of several hundred. Area farmers reported a good harvest of our test cultivar during the same time frame. When the fruit was cut, there was an amazingly small number of seeds. Flowering occurred at an extremely small plant size, and the vines failed to grow normal length.

Chlorosis in foliage is a common symptom. Marginal yellowing, intervenal yellowing, and a general unhealthy appearance are often seen. While these symptoms are sometimes indicative of nutritional problems, tissue analysis and soil analysis indicate "not this time."

Distortion of foliage is another symptom. It ranges from cabbage heading, when tight apical growth gives a cabbage-like appearance, to leaf deformity. It is not uncommon to find dinner plate shapes, shapes like a scimitar, strap leaves, and other irregular shapes, which would leave a mathematician at a loss to describe.

On some species of plants, the stems seem to have lost their rigidness. I have dogwood and viburnum which were growing vertically in the early spring that later in the summer were lying over in the containers.

We do not raise many types of monocots, but the effect of the Benlate syndrome does not seem to appear as dramatically. Root symptoms are much less pronounced than in dicots. However, brittleness of the tips and clubbing often are still found. Distortion of the foliage is dramatic. I have seen blades of African iris and liriope folded to accordion-shaped pleats. Many of these pleats are in the middle of leaves. More common is a rippling of the foliage in one or more places on the blade. A majority of the leaves also will grow spiraled into a corkscrew form or in a crescent shape.

Palm fronds emerge and often fail to separate and fan out normally. The fronds remain attached at the tip. I have seen several plants with this type of frond exhibited on more than two growth whorls. Some of the same frond pleating seen in iris occurs on palm fronds, too.

Throughout the nursery, we have seen a disappearance of insects. Before the appearance of the Benlate syndrome, we were forced to spray continually for sweet potato whitefly. We have not seen any in more than a year. Aphids like sweet viburnum so much it seems they get passports from nearby Latin American countries just to come eat. We haven't seen any significant population in months. In central Florida, scales are one of the most significant insect problems. Populations of false oleander scale have decreased to nearly nothing and other species are just not found in my nursery.

One of the most significant observations is the absence of fire ants. Two years ago, mounds popped up everywhere. We constantly had to battle fire ants. The only areas where I have been able to find mounds lately are in our parking lots.

The effect of the Benlate syndrome will be felt for a long time. It has had significant economic impact on nurseries in central and south Florida, and probably many other areas. The problem is very real, and if you buy plants from other producers, don't discount the severity of this problem.

Container Nursery Nitrate Nitrogen Runoff: A Six-State Summary

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INTRODUCTION

The environmental awareness of society necessitates that nursery operators understand and justify the nutrient management strategies used in production of container-grown plants. Due to the large amount of fertilizer used in container-plant production, nutrient runoff is a potential source of surface and groundwater pollution. Wright and Yeager (1980) have demonstrated that NO_3-N leaches from a pine bark medium fertilized with ammonium nitrate and Yeager et al. (1980) determined that 'Helleri' holly grown in a pine bark medium and fertilized once a week with 300 ppm nitrogen (N) in the irrigation water utilized 19% of the N applied. In further studies by Yeager (unpublished) 31% of N, surface-applied as Osmocote (18-6-12), was used by dwarf yaupon holly (plant plus medium) grown in a greenhouse for 26 weeks. Hershey and Paul (1982) evaluated N loss from chrysanthemum containers fertilized with a surface application of Osmocote (14-14-14) and found that 15% to 29% of the N released from Osmocote leached in 11 weeks. These laboratory and greenhouse studies indicated that NO_3-N leaches from the growth medium; however, data are not available that document the loss of NO_3-N from the plant production area. Thus, the impact of container plant production on surface or groundwater pollution is not known. A study was conducted in 1990 to survey NO_3-N concentrations of container plant production

area bed runoff, reservoirs or ponds that contained runoff, wells on nursery property, and surface water discharged from the property or border.

PROCEDURES

Two or three samples were taken at each collection point that included bed runoff, reservoirs or ponds containing runoff water, wells, and property borders. Samples were collected at approximately 6-week intervals during the 1990 growing season in the states of Alabama, Florida, New Jersey, North Carolina, Ohio, and Virginia. In each state one to five nurseries were sampled that used either controlled-release fertilizers or controlled-release fertilizers supplemented with solution fertilizer in the irrigation water. Controlled-release fertilizers used at these nurseries included those in which nitrogen release was influenced by substrate moisture, temperature, or biological activity. Container plants grown at the nurseries sampled generally included one-, 2-, and 3-gal hollies, junipers, and azaleas as well as a few deciduous plants at some locations.

SUMMARY OF RESULTS

Data averaged over sampling time and nurseries in each state indicated that runoff from production beds where only controlled-release fertilizers were used had an average NO_3-N level of 8 ppm with a maximum of 33 ppm recorded. Samples obtained within a few weeks of fertilization usually contained the highest NO_3-N concentrations, while samples obtained several months after fertilization were usually below 10 ppm NO_3-N, the federal drinking water standard (Anon., 1982). This does not mean that all controlled-release fertilizers resulted in runoff NO_3-N levels greater than 10 ppm immediately following fertilization; however, the time of sampling relative to fertilizer application is an important consideration in interpreting results for production-bed runoff.

Controlled-release fertilizers supplemented with solution fertilizers resulted in average bed runoff of 20 ppm NO_3-N with a maximum of 135 ppm recorded. Nitrate N concentrations in surface reservoirs that contained runoff from areas fertilized with controlled-release fertilizer and controlled-release supplemented with solution fertilizer averaged 4 and 6 ppm, respectively, with a maximum of 20 and 23 ppm, respectively. Nitrate N in surface water leaving the property averaged 5 ppm for both fertilization programs with a maximum of 20 and 30 ppm, respectively, recorded for water leaving the property of nurseries using controlled-release fertilizer supplemented with solution fertilizer and nurseries using only controlled-release fertilizer. Average and maximum NO_3-N of well water for nurseries using only controlled-release fertilizer and nurseries using controlled-release and supplemental solution fertilizers were 5 and 7 ppm and 17 and 55 ppm, respectively.

These data provide a benchmark for developing and implementing efficient management practices and fertility regimes that minimize nutrient loss from the nursery producing container-grown woody ornamental plants. Considerable research is needed to provide specific recommendations for using fertilizer efficiently in the nursery.

Based on these data and our experiences with nutrient management, we recommend the following management practices.

1) Monitor NO_3-N levels of the container medium, production-bed runoff, well

water, runoff water in collection reservoirs, and water discharged from the property. Maintain records and develop a data base of information to justify changes in the fertility program.

2) Monitor irrigation duration. Excess irrigation can contribute to NO_3-N runoff.

3) Determine efficiency of irrigation systems and modify systems as needed to improve efficiency.

4) If controlled-release fertilizers result in excessive NO_3-N levels in runoff immediately following fertilizer application, consider applying controlled-release fertilizers to beds or crops sequentially over an extended period of time rather than fertilizing all plants within a runoff area within a short time.

5) If you use reservoirs to capture runoff and rain water, you may need to line reservoirs and ditches to prevent groundwater contamination. Several connected reservoirs may facilitate more biological degradation than a single reservoir.

6) Use grass filter strips in surface waterways.

7) Calibrate spreaders and other fertilizer application equipment.

8) Place solution fertilizer tanks on concrete aprons that surround the tank and will contain spills. Check specific state regulations regarding construction details.

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Hiring and Keeping Good Employees

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Labor cost is the largest single expense in growing and selling plants. Consistently, nurserymen tell me that 20 to 60% of the operating cost is labor. Many of the associated costs such as fertilizer, pesticides, plant tags, and electricity are insignificant in comparison. Consequently, lowering labor cost is one of the most effective ways for a manager to increase year-end profit.

The people in your organization will determine your company's ability to grow and expand. Quality personnel will not only improve efficiency and reduce labor costs but also free owners and operators to do much-needed travel. I am often asked how our company locates and keeps quality personnel. I consider quality people one of our major strengths.

OUR ORGANIZATION

We have various levels of employees including basic laborers, skilled laborers, crew leaders, supervisors, and managers. The majority of our people are hired as laborers. They perform routine labor tasks such as weeding, planting, and tagging. From the pool we expect some to develop into skilled laborers, crew leaders and, later, supervisors. Spray applicators, equipment operators, and truck drivers are examples of skilled labor.

Once skilled laborers are identified they seldom develop to a higher level, not because they lack opportunities but because when they become good at a skilled position, they want to stay at that level because of job satisfaction.

Crew leaders come directly from the basic labor group. Some crew leaders step forward and become supervisors when opportunities arise. Seldom is a crew leader hired. Occasionally, because of previous job experience, we hire a crew leader. The same is true of supervisors. Supervisors most often arise from the ranks of the crew leaders. Managers have been hired from outside the organization but generally come directly from the supervisory pool. Basic laborers may work as part of a crew or a team to accomplish a task. The preferred arrangement is to work as a unit of one so performance and incentive pay can best be coordinated.

Crew leaders oversee a group of six to 12 people. They make more per hour than the crew members because of their leadership and organizational responsibilities. However, they can be rewarded by sharing the incentive rewards of their crew. They are expected to work along with their crew.

Skilled people are paid at a higher pay scale than laborers according to skill. They are not on incentive performance pay because generally quality and not quantity work is our first priority.

Supervisors coordinate the activities of 13 to 40 laborers and crew leaders. They are paid mostly salary with some bonus rewards. Managers oversee a much larger operation like a whole nursery, a nursery unit sales, a division; or they may be responsible for sales or production in all our nursery units. They are paid in a similar way to supervisors.

HIRING

The ideal employee has certain characteristics:

1) Energy, a drive to accomplish tasks and reach goals;

2) Communications skills, the ability to understand and to be understood and the willingness to use that ability;

3) Honesty and trustworthiness;

4) Flexibility, a willingness to do whatever is necessary to benefit the company;

5) Compatibility, the ability to adapt to an assignment and maintain a pleasant attitude;

6) Dependability.

Our company is not made up of 600 perfect employees. From top to bottom each of us is weaker in some areas and stronger in others. The challenge is to maximize the strengths and strengthen the weaknesses. Spotting undesirable characteristics that cannot be corrected and taking action is called effective firing. Everyone makes hiring mistakes. Accept that, and prepare yourself to respond in the interest of the company and other employees.

Interviewing prospective employees should first include a clear description of the job. Take the time to write a job description with a clear description of working conditions. Tell the employee how hot, cold, or wet it can be. Explain the pay policy and explain any performance incentive programs. We generally start labor at minimum wage and provide piecework programs that can add up to $200 per week to their paycheck.

Interviewers should judge the prospective employee from body language, eye contact, and responsiveness to explanations. Athletes make good employees. State your working hours. Discuss your safety policy. Be sure that your company is familiar with and abides by the newly effective ADA law. The American Disabilities Act protects disabled workers from work-place discrimination.

At this time we might make a conditional offer of employment. The applicants who accept fill out a personal health history. You then hire those you think can do the job and explain benefits such as life insurance, health insurance, accident insurance, profit-sharing retirement plan, and vacation allowances. The benefit allowance package is very important in attracting and keeping good employees.

Our company offers family medical coverage at a reasonable employee cost after 6-months employment. After 9 months employees are given paid holidays. They are eligible for one week paid vacation per year after one year employment. Employees are insured for accidental death for $15,000 after 6 months' employment. They also receive a life insurance policy valued according to their last year's earnings. The spouse is covered for $5,000 and each child at $2,500. This policy is effective after 6 months.

Another attractive condition of employment at our nursery is our emphasis on employee safety. Both OSHA law and our insurance company require a sound and meaningful safety program. We find that stressing employee safety lets employees know the company values them and is concerned for their welfare. Part of our safety policy features drug testing. Any employee who caused an injury is also tested. A positive test can be grounds for immediate termination.

We call a prospective employee's references. We don't hire people who have never been employed by the same company for at least one year, unless they are just out of school. Prospective employees who have drifted into the area recently stand a

poor chance of employment. We have them complete the I-9 immigration form which requires two proofs of citizenship, such as a driver's license, birth certificate, passport, or social security card.

KEEPING GOOD EMPLOYEES

Why do I stay with my present employer? I think my employees derive job satisfaction for the same reasons I do. If I can develop an employee-employer relationship that would satisfy me, I believe employees would also be satisfied and become long-term, good employees.

I am satisfied with my job because I like what I do and am part of a successful team. I consider my job permanent, which provides security for my family. The pay is good and the benefits are excellent. The owners of our company have let me know my services are valued. They are interested in my family and like to hear of their progress. They share my pride in their accomplishments. They allow me to participate in family activities by giving me flexibility to mesh my family and my job.

My job responsibilities are realistic, based on my experience and education. I have reasonable opportunities to grow, expand, and be creative. My immediate boss listens to work problems I encounter and, if possible, promptly helps me solve those problems. I sense his approval for successful projects. The people that are on my team are responsible, responsive, eager to help, trustworthy, and fun to be *around*.

My boss encourages me to rise to higher levels by pulling other employees up. He discourages me and others from trying to rise by putting others down. My employer pays me enough so that I don't consider employment by the competition. My employer pays me enough to solve my personal and financial problems, freeing me to solve his business problems.

I try to treat my employees like I like to be treated. I consider their ideas fairly. Even if one of their ideas is not new to me, I try to listen carefully and show interest. I can use this as an opportunity to help the person learn and gain experience. I also consider the possibility that conditions have changed since I tried this idea, and it may work now. Show an open mind. Encourage creativity. The most powerful asset your employee has is a brain. Your next significant cost-saving measure or profit-producing technique could possibly come from someone you least expect. Don't dwell on past minor mistakes. They may arise out of ignorance and may reflect poor management practices or failure to train employees properly. The second time one makes the same mistake is serious. The second time the mistake is because the employee failed to learn. Analyze the situation carefully because today's failure to learn can cost someone's life or business.

As a manger I try to provide a vision. That vision begins with where we have been, where we are today, and where we plan to be tomorrow. Good employees expect to be informed, and they should be.

Good employees contribute their abilities and share their knowledge also. They efficiently produce our beautiful nursery.

I respond to compliments from visitors by saying that I did very little. I try to tell employees about these compliments. However, I stand squarely with my people in accepting responsibility for problems and disasters. Mistakes must be shared. The next step is to help find out what went wrong and take steps to prevent the problem

from arising again. We don't want to be full-time problem solvers. We want to prevent the problems instead.

FOSTERING AN ATMOSPHERE OF TEAM SUCCESS

The operation of a nursery is similar to a sports organization. How concerned are owners about winning? Do they risk their resources? Are they willing to provide whatever it takes to win? How good a coach am I, or are you? How good is your point guard? How well does your sales manager perform? Do you and I create a team of can-do attitude with positive criticism, praise, rewards, and training, or do we instill fear of reprisal and penalties. Have we developed personnel who are willing to stick cuttings because that is the greatest opportunity today, or do they say that is not their job? Do I have team meetings to make my points as well as to hear their concerns? Do I treat people as individuals and use different techniques to motivate and communicate based on their personality differences? The employees of your nursery and the jobs they perform are like a chain. As the lead or coach should I pull the chain or push the chain? Are you pulling or pushing at your nursery?

The big challenge to nursery owners and operators is not to grow, sell, and ship the plants. The challenge is to find and keep good people to grow, sell, and ship the plants. As nurserymen we don't grow the good plants; we provide an environment for the good plants to grow. We don't hire good employees, we provide the environment for the good employees to grow. We will be successful in the nursery and in life if we are successful in making individuals a success.

Give responsibility and expect accountability. Give reasonable workplace freedom. Develop communications. Share prosperity. Share business concerns. Provide leadership. Be reliable as an employer. Don't tolerate weeds and certainly don't produce weeds. To have good employees you have to be a good employer.

"New" Plants/"Old" Plants

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Great plants are few and far between. Each year at hundreds of nursery and propagation conferences across the country, audiences are bombarded with a plethora of "new" plants. They have great promise, yet only a few attain commercial success. The following appear to offer more than simply promise and are already in production.

Abelia × *grandiflora* 'Confetti'. *Abelia* × *grandiflora* 'Sherwoodii' provided a cream-margined branch sport that was named 'Confetti' by Jim Berry, Flowerwood Nursery, Mobile, Alabama. It is compact and mounding with foliage that will brighten shady areas of the garden. Cold weather induces a pinkish to rose tinge to the creamy variegated areas. Ideally, it should be used in mass for maximum effect. I estimate it at 2 to 2½ ft high and 3 to 4 ft wide at maturity.

Acer buergerianum. The trident maple is a plant I have mentioned many times for use in hot, dry, stress-laden environments. The lustrous dark green foliage, gray-orange-brown bark, and restrained, 20- to 30-ft growth habit are notable features. Unfortunately, fall color is variable with orange and red more the exception than the rule. Tree Introductions, Inc., Athens, Georgia, has selected a faster-growing, red burgundy fall-coloring clone that has been successfully propagated from summer cuttings using 5,000 to 10,000 ppm KIBA.

Aesculus parviflora. The bottlebrush buckeye, a superb summer, white-flowering shrub, is perennially in short supply. Seeds are the logical method of increase and should be planted immediately after collection in September and protected from vermin. Cuttings can be rooted, but are difficult to manage because of size. At Georgia, I am now using stooling beds with about 24 to 30 in. of pine bark. The suckers are divided in late winter and placed in 3-gal containers. The divisions make full plants at the end of one growing season

Calycanthus floridus. The common sweetshrub offers lustrous dark green summer foliage, yellow fall color, and variably fragrant maroon flowers. We have assembled three fragrant clones: 'Edith Wilder' from Swarthmore College; 'Michael Lindsay' from Allen Bush, Holbrook Farm; and 'Trainer House' from a local source. 'Michael Lindsay' is outstanding with fruity aroma, lustrous, bullate-puckered, almost black-green leaves and compact habit. Cuttings are rooted using firm wood (June-July), 3,000 to 5,000 ppm KIBA, perlite or 3 perlite : 1 peat (v/v) medium under mist. Cuttings are injured by alcohol-based rooting hormones and excess moisture.

Carpinus caroliniana 'Upright Form'. The upright American hornbeam was selected by Tommy Strickland, for upright habit resembling the upright European hornbeam. This clone could be a valuable addition to the palette of southern native plants for screening and hedging.

Clethra alnifolia. The summersweet clethra is becoming fashionable because of handsome foliage and sweetly fragrant summer flowers. The typical species is variable in growth habit and size while 'Hummingbird' is low-growing (30 to 40 in.), forms suckers, and colonizes. Plants have lustrous dark green foliage and 4-in. long white flowers. In our work, 'Hummingbird' and the other cultivars root

faster, more uniformly, with more profuse root systems when treated with 1,000 to 3,000 ppm KIBA quick dip.

Fothergilla major 'Mount Airy'. Mount Airy large fothergilla was selected by this author for large flowers (often 2 in. long and 1 in. wide), superb orange-red fall color, vigorous growth, and ease of rooting. It has performed well in Zones 5 through 8. The parent plant was 5 ft high and 6 ft wide. At Georgia, we root it from soft and firm-wood cuttings with 3,000 to 5,000 ppm KIBA.

Hydrangea arborescens subsp.*radiata*. This silver-backed leaf form of the smooth hydrangea is a stunning addition to the shade garden. The 4- to 6-in. diameter, flat-topped flowers have sterile outer sepals with fertile flowers in the center, which are not showy. The cottony-white undersides of the leaves, when buffeted by the wind, are particularly striking. The species will grow 3 to 4 ft high and wide. We are looking for two sterile-flowered forms, which have been described.

Myrica cerifera. The southern waxmyrtle is a fragrant-foliaged evergreen shrub that is widely used for screening. Several new compact low-growing types like 'Fairfax' and 'Georgia Gem' can be used for grouping and massing in landscapes. Woodlanders, 1128 Colleton Ave., Aiken, South Carolina 29801, has several low-growing compact selections that should be tested by larger commercial firms. It is easily propagated from summer softwoods—IBA does not improve rooting.

Illicium species. Anise species are superb broad-leaved evergreens for use in Zones 7 to 9. They are sturdy, with large rhododendron-like, olive to dark green leaves and white, yellow, pink to red flowers. All species prefer shade. *Illicium henryi* (Henry anise),*I. floridanum* (Florida anise), and*I. parviflorum* (small anise) are the most cold hardy and best adapted for landscape use. All propagate readily from firm cuttings anytime of year with 3,000 ppm KIBA. Use bottom heat if cuttings are rooted in the winter.

Loropetalum chinense var. *rubrum*. The pink Chinese loropetalum has the ornamental potential to become a great commercial and landscape success. Outstanding ruby-red to maroon-green evergreen foliage and vibrant salmon-pink flowers on a 4- to 6-ft (10 ft) framework will endear it to gardeners, landscape architects, and nurserymen. Rooted cuttings I brought home from the Arnold Arboretum in mid-September 1991, completely filled a 3-gal container by fall of 1992. Cold hardiness is undefined but I venture adaptability between Zones 7b and 9. Fortunately, it has been easy to root, and extremely soft cuttings forced under lights as well as firmer cuttings respond favorably to 1,000 ppm KIBA.

Sassafras albidum. The common sassafras is seldom available in commerce because of transplanting difficulty. Root cuttings taken early February 1992, produced 2- to 3-ft high plants by September. The small cuttings were transplanted to Spin Out™ treated containers to increase root development. Spin Out™ containers contain copper that chemically prunes young root tips and promotes secondary branching. This process has worked extraordinarily well. This root cutting-Spin Out™ process may lead to the selection of superior clones.

Styrax japonicum 'Emerald Pagoda' ('Sohuksan'). The emerald pagoda Japanese snowbell was introduced by Dr. J. C. Raulston, North Carolina State University, for its larger, leathery dark green leaves and waxy white flowers. It has proven more heat tolerant than the typical species in Zone 7b. Softwood cuttings can be rooted using 3,000 to 5,000 ppm KIBA. They are slow to root and may prove difficult to overwinter.

Budding and Grafting of Fruit and Nut Trees at Stark Bro's

Bob Patrick
Stark Bro's Nurseries, Louisiana, Missouri 63353-0010

As a propagation foreman for Stark Bro's Nurseries & Orchards Co. of Louisiana, Missouri, I would like to give you an overview of my company's general propagation technique and some specific information on a machine bench-graft technique we have recently perfected.

Stark Bro's Nurseries and Orchards Co. is 176 years old and currently produces and markets 1.5 million fruit trees annually. We market many more small fruit, ornamental, and hardgood items through our mail order, wholesale, and commercial-orchard sales operations, but the production and sale of fruit and nut trees is the backbone of our business.

With home offices at Louisiana, Missouri, the company maintains nearly 1,200 acres of field production operations in Missouri, Illinois, and California. We are most noted for the development of the red and golden delicious apple cultivars that together account for 60% of the world's current apple production.

Stark Bro's current product offering includes 207 cultivars of deciduous fruits and nuts. Propagating this number of cultivars to 27 rootstock cultivars results in nearly 1,000 scion/root stock combinations, which must be tracked through our production, storage, and shipping operations. The first step in this long process is the timely placement of the scion cultivar onto the rootstock.

At Stark Bro's, we employ five asexual propagation techniques in combining scions to rootstocks:

1) T-budding
2) Chip budding
3) Bench grafting (whip and tongue)
4) Crown grafting (whip and tongue)
5) Machine bench grafting

All understocks used by Stark Bro's are purchased as liners from outside vendors except for peach and nut understocks, which are planted as seeds primarily collected from local sources. All of our propagation is conducted by full-time employees.

Scion wood is obtained exclusively from our scion orchard blocks, which are maintained as hedgerow trees. Budsticks are cut and the leaves removed one day prior to being used. Our budding season runs from early July through mid-September. Dormant wood to be used in our winter bench-grafting and spring crown-grafting operations is harvested from the scion orchards in early December.

For the past two years, we have shifted our entire budding operation to chip budding. We find that chip budding provides us with better stands and straighter, more uniform tree growth. In collecting bud sticks for chip budding, it is important to match the caliper of the budstick with the caliper of the rootstock shank.

In the chip budding procedure the receptive cut on the rootstock is made first. This requires two cuts. The first is made to a depth of about one-eighth inch at an angle

of 20 degrees to the stem to form the basal lip of the cut. The second cut is made 1 to 1½ in. above the first, entering the stem at the same 20 degree angle and then cutting down to meet the base of the first cut. In similar fashion, a chip of matching scion wood is cut from the bud stick and placed in the receptive cut on the understock. The length and width of the scion chip should be slightly less than the chip of understock it replaces and should never be larger. The lip of the receptive cut holds the scion chip in place until it is wrapped.

We use 1/2- × 12-inches strips of clear 2-mil polyethylene to secure the scion chip to the understock. The material we use is slightly elastic, which allows for a more secure wrap. The bud is completely covered in all cases. Bud unions are usually sufficiently callused in 30 days, at which time the plastic wraps are removed. A good budding team can place and wrap 2,500 to 3,000 chip buds in an eight-hour day. Bud stands often approach 100%, and those buds which fail to "take" are rebudded to fill out the stand.

Historically, the apple bench-grafting program at Stark Bro's was designed around several skilled technicians using the whip-and-tongue method of hand grafting. This system has proven successful over the years and has produced as many as 2.5 millions bench grafts a year during the winter months of January and February. In recent years, however, with the expansion of our operations to the West Coast the ability to maintain the necessary staff of trained grafters has become more difficult. With the addition of our California operation in 1987 our bench-grafting program has increased to include another half million Malling apple grafts. At the time of the acquisition, Agrisun Nursery was making about 200,000 bench grafts a year of both apples and cherries. To accomplish this they had developed a program that incorporated the use of a hand-operated French grafting machine. We found this unit to be too slow, and because of the uneven pressure, the cambial tissue was often torn, or the scion was jammed in the machine. With the help of the California staff, we have developed our new machine.

The pneumatic machine we are currently using was designed in-house and requires 130 to 150 pounds of air pressure to operate efficiently. One large compressor stored in another adjoining building operates the eight machines. We did this to avoid the noise. Each machine has a silencer tube running beneath the table to muffle the noise. The machine cut is a standard cleft-graft cut approximately one inch long. We do like this cut better than some of the smaller notch type or omega cuts made by many of the grafting machines developed for the grape industry. This larger cut allows for more cambial contact and a stronger graft union than others we have tried.

Machine grafting brought a new approach to bench propagation. We have found it to have four advantages:

1) Machine grafting does not require a long training period, usually a single full day, if the employee is fairly dexterous.

2) We experience fewer injuries related to muscle strains, carpal tunnel syndrome, or other similar problems.

3) We can make larger caliper grafts with much less effort than with hand grafting, giving us much more flexibility in matching the scion to the rootstock.

4) We waste less material because the machine can use larger scions and rootstocks than we could use with hand grafting. The grafting machine system is an assembly-line approach using eight machines and five teams of employee. The

first group of three to four employees prepares the rootstock by removing all the secondary branch roots from the main tap root, or from clonal rooted cuttings, back to ¼-inch root initials. The second team of two people cut the scion-wood sticks into 5-in. lengths with a bandsaw. The roots and scions are then placed in separate plastic tubs.

The next two teams are the eight grafting-machine operators. The first four machine operators make the point cuts on the basal end of the scions. At the same time the other four grafting-machine operators are making notch cuts on the rootstock sections. We prefer this method of notching the rootstock rather than the scion because we have found that many of the cultivars we currently have in production tend to split when the notch is cut. This reduces the chance of a successful graft. The points and notches are made quickly and transferred from one tub to another for transport to the wrapping line.

When the wrappers receive the tubs of scion points and notched rootstocks, they put the scion and rootstock together, carefully matching the diameter size of each piece. Then starting at the top of the scion and wrapping downward, the wrapper firmly places an air-tight wrap over the graft union. Seedling grafts are wrapped with biodegradable cloth tape. Clonal grafts are wrapped with a very economical light-grade masking tape.

In Missouri the grafts are counted and moved to the packing station where the grafts are dipped in rose wax from the scion end to the taped union of the graft. Then the grafts are packed in damp dog-hair moss in a 16-in. × 16-in. × 4-ft box, lined with kraft paper.

The boxes are moved into our callusing room and allowed to callus at 70°F for about 12 days. Once the grafts have formed sufficient callus, they are moved to our cold storage building and stored at 35°F until planting. Planting is scheduled for the first week in April, when the grafts are removed from storage and machine planted at our Illinois growing site.

At the California plant the bench grafts are taken directly to the field and planted during January and February. Due to the diversity of the many products Stark Bro's produces and the variability in types and sizes of propagation material, growing location, and marketing programs, there will always be a place for some hand grafting. However, as we look toward the future, machine grafting offers a new practical approach to producing economical nursery stock.

Propagation of Southern Perennials

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INTRODUCTION

At Southern Perennials and Herbs in southwest Mississippi, we propagate all of our perennials. Herbaceous perennials maybe propagated year-round in the Deep South. Cuttings may be propagated during the growing season. Divisions and root cuttings are usually made during the dormant season. Seeds may be germinated all year.

STEM CUTTING PROPAGATION

Cuttings of perennials are propagated during the growing season on plants that cannot or should not be grown from seed. Cutting propagation rather than division is generally preferred during the hot summer months. Candidates for cutting propagation are, naturally, those that form above-ground stems with nodes, but not rosette-forming perennials such as *Hemerocallis*.

We prefer to take cuttings only during cloudy periods of the day in summer or in early morning or late evening. It is very important to keep cuttings from wilting before they are placed under mist. A beneficial practice, particularly for difficult-to-root perennials, is to place stock plants in shade for a couple of weeks before cuttings are taken. If cuttings must be taken during sunny periods, exercise great care to avoid wilting.

We take cuttings from soft, new growth. We use mostly tip cuttings but sections of stem that are still relatively soft may be used. For most perennials, cuttings should be 3 to 4 in. long. Usually, we take single- or double-node cuttings from upper stem sections, or 3-in. tip cuttings.

We don't strip cuttings unless they physically can not be inserted into the rooting medium without being stripped. Cuttings are stuck just far enough into the medium so that they remain upright.

Before being stuck, all cuttings are dipped in Dip 'N Grow rooting hormone at a concentration of 10 : 1 (water : DNG). We dip all cuttings, even the easy-to-root cultivars. Though this is not necessary for root initiation on many cultivars, it is done to insure uniformity of rooting. We've tried various concentrations of rooting hormone, but 10 : 1 Dip 'N Grow works best for us for general use. Dip 'N Grow is 1% IBA plus 0.5% NAA. Treated cuttings are stuck in 72-cell, deep plug trays and placed under intermittent mist under a bench in the greenhouse.

Cuttings must be checked regularly for root initiation, which may take as little as four days. They are promptly removed from mist as rooting begins. Rooted cuttings remain in shade for several days, then are placed outside in the general nursery area. Cultivars that root rapidly may be potted into 1-qt or 4-in. pots in as little as 3 weeks from the time the cuttings are stuck, especially in late spring or early summer when growth is most rapid.

DIVISION

Division of perennials is primarily a cool-season activity, but there are notable

exceptions. Warm-season grasses such as *Miscanthus* and *Pennisetum* must be divided during warm weather. *Elymus*, along with other cool-season grasses, on the other hand, must never be divided in warm weather. Other perennials that we usually divide during the summer are hemerocallis, Louisiana hybrid iris, hosta and, when the need arises, certain other easily grown perennials. Summer division usually requires extra attention to moisture requirements of sensitive perennials.

Cool-season division is straightforward for rosette-forming perennials; simply divide so that new plants have active roots and at least one rosette. The foliage on leafy types is trimmed by half or more, if not already trimmed by frost. For stoloniferous perennials, stolons or rhizomes are placed just beneath the surface of the container medium. Three to five or more pieces are used for slender-rooted cultivars. Some perennials with particularly tough root systems are simply chopped into vertical sections, pieces small enough to fit in a plug-sized container.

Our root-cutting propagation is very limited, so we don't feel adequately experienced to comment on procedures.

SEED PROPAGATION

Seed propagation goes on all year. Most perennial seed is sown into 72-cell, deep plug trays. We never cover any seed. The trays are placed under mist, under a greenhouse bench, and treated the same as cuttings. Seed trays are removed from mist a day or two after they germinate. They are then placed on the greenhouse floor, under shade in summer, where they are kept for a week or more until the seedlings are large enough to be placed outside with the general nursery stock under overhead irrigation. Trays are kept here for several weeks until they are rooted enough to plant into one-quart pots. There is no attempt to regulate temperature during germination. The ambient temperature of the greenhouse is generally adequate for good germination of most cultivars. We have learned, though, that certain ones are best sown during specific seasons, presumably due to the prevailing temperature. For instance, *Rudbeckia fulgida* 'Goldsturm' needs a warm temperature to germinate well, and attempts to germinate this cultivar during winter invariably meet with failure.

Our refusal to cover seed with soil contradicts the recommendations from seed company catalogs and seed propagation texts, as do the temperatures and times required for germination. Nevertheless, we almost always get good results and often get faster germination than is cited in these references. This is probably due to a combination of surface sowing and maintaining temperatures much higher than recommended. Since the trays are shielded from direct sunlight, the darkness requirements of certain seeds are adequately met. The requirement of certain other types for light during germination is met by preventing the seed trays from being in total darkness. We realize this is rather unscientific, but it works for us.

We collect seed of a number of perennials from stock plants kept in our display gardens. Some seed is collected from container plants, though this is not the preferred method, since seed is often ruined by irrigation. Seed collected from our plants is usually sown soon after collection, though some is stored for extended periods. We collect seed of *Lilium phillipinense*, and this seed must be sown immediately. *Lobelia cardinalis*, however, can be kept viable for at least two years. Our seed-storage area is simply cardboard boxes in an air-conditioned office, kept at about 80 to 85°F during the summer and at about 65 to 70°F during the winter.

CONCLUSION

Our propagation methods have been developed over a period of several years. Since many of our procedures contradict conventional wisdom, we can only conclude that propagation, while a scientific endeavor in many of its aspects, requires the intuitive dedication of a plant's person to achieve its fullest potential.

An Inexpensive Propagation Structure

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At Byers Nursery we currently stick about 900,000 softwood cuttings each season. Our plant mix consists of crapemyrtle, birch, maple, viburnum, holly, dogwood, and other shrubs and trees.

In 1988 we had twelve 24- × 95-ft quonset houses that would hold about 600,000 cuttings. We wanted to expand our production area with the minimum monetary expense. In considering ideas from local propagators Don Shadow, Freddy Alonso, Carl Bauer, and Milton Schaefer, and those seen on I.P.P.S. tours at Turkey Creek and Simpson Nursery, a small 4- × 95-ft quonset bed seemed to be the most cost-effective.

Some of these bed designs have used landscape timbers or concrete for sideboards and metal conduit pipe or concrete reinforcement wire for the arches to support the plastic. The price of these products varies greatly, but usual costs are: landscape timbers, $48/bed; concrete reinforcement wire, $40/bed; ½-in. metal conduit, $35/bed. Concrete varies with just how much is used.

We took this concept and simplified it to use concrete rebar and PVC pipe. Each small quonset consists of 40 pieces of 3/8-in. × 16-in. concrete rebar, pushed 12 in. into the ground and spaced at 5-ft intervals along the sides of the bed. A 6¾- ft piece of ½-in. schedule-40 PVC pipe is placed over the rebar on one side of the bed, then bent and placed over the rebar across the bed, forming the quonset structure.

The price of the rebar is $7.33 and the PVC pipe is $12.60, for a total of $19.93 per bed. These materials may be used as many as four times per season and are reusable from season to season.

The length of these structures can vary. We chose 95 ft because of the ability to use the same portable mist lines used in our large quonset houses. Any clear plastic, 8 to 10 ft wide, will work with the appropriate shade. Not only shade but also 6- × 6-in. ventilation holes, cut about every 10 feet and on each end, are needed because of the intense heat at plant level.

This flexible, simple, and inexpensive structure is the most cost-effective and efficient propagation structure we currently use.

Update On Root-Promoting Chemicals and Formulations

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INTRODUCTION

In my 20 years as a member of this society, I have read more papers and heard more questions about root-promoting chemicals than any other subject. Members have eagerly tested chemicals and formulations, but none has been as effective as indolebutyric acid (IBA) and naphthaleneacetic acid (NAA) (Dirr, 1981; Dirr and Heuser, 1987).

A major hurdle to the development of new root-promoting chemicals, particularly in the United States, is the EPA registration process. The chemical must undergo screening for toxicity to a wide range of organisms. Since the root-promoting chemicals are categorized as minor-use compounds, companies are not enthusiastic about spending the necessary money to bring them to market. A recent estimate placed the cost between 4 and 10 million dollars for the introduction of a new non-food chemical like IBA.

IBA and NAA are legally registered for use in plant propagation. Theoretically, plant propagators cannot buy and use the actual chemicals. They must purchase products from end-use formulators that have been approved by EPA. Read the labels on products like Dip 'N Grow, Hormodin #1, and Hormo-Root. An EPA Registration Number appears on each formulation. For example, Hormodin 1, 2, and 3, represent 0.1%, 0.3%, and 0.8% IBA in talc. Each concentration has a separate EPA number.

AVAILABILITY AND COSTS

IBA, NAA, and the potassium salts of each can be purchased from companies listed in Table 1. Always purchase the gamma form of IBA and the alpha form of NAA. Consistently, the potassium (K) salts are higher priced than the acid formulation. Table 2 provides a guide to costs based on fall 1992 catalog prices. NAA is always less expensive than IBA, but is not as broad-spectrum effective. I seldom use NAA; the salt of IBA has become the common denominator in our propagation program.

STORAGE AND PURITY

The chemical companies recommend that IBA be stored at 32 to 41°F and NAA at room temperature. However, Research Organics, Inc. recommends storing the K-salts of IBA and NAA at room temperature. I have found that refrigerator storage of both works well.

The stability of IBA solutions is perennially debated. Robbins (1987) reported that a 5,000 ppm solution of IBA was stable and maintained biological activity for six months. Storage temperatures of 72 to 77°F, 32°F, or 43°F made no difference. However, significant loss of activity occurred after 19 months.

Often propagators are overly concerned about the absolute concentration of the rooting powder or solution. Be as accurate as possible, but the actual IBA is 97 to 99% pure, NAA 95%. This means that for every gram (1,000 mg) of 97% IBA, 30 mg are something else. In short, the propagator starts with a 3% error for IBA or

Table 1. Suppliers and costs of alpha-naphthalene acetamide, alpha-naphthaleneacetic acid, potassium salt of NAA, indolebutyric acid, and potassium salt of IBA.

Alpha-NAA	NAA	KNAA	IBA	KIBA
		ICN*[1]		
10 g - $6.35 25 g - $11.45 100 g - $31.80	25 g - $8.75 100 g - $23.45	N/A**	1 g - $5.70 5 g - $17.80 25 g - $50.15 50 g - $94.05	5 g - $18.85 25 g - $81.10
		Sigma[2]		
10 g - $4.70 25 g - $9.35 100 g - $26.00	25 g - $8.90 100 g - $23.60	N/A	1 g - $5.70 5 g - $17.25 25 g - $46.10	1 g - $7.55 5 g - $17.35 25 g - $46.20
		Research Organics[3]		
N/A	25 g - $7.95 100 g - $21.60 1 kg - $198.50	25 g - $10.50 100 g - $32.00 1 kg - $276.00	5 g - $6.75 10 g - $11.70 100 g - $91.00 500 g - $420.50 1 kg - $786.00	5 g - $11.85 50 g - $76.50 500 g - $595.00
		U.S. Biochemical[4]		
N/A	N/A	N/A	1 g - $3.65 5 g - $8.85 25 g - $34.25 100 g - $129.50 1 kg - $1,276.80	1 g - $4.05 5 g - $12.30 25 g - $49.15
		Aldrich Chemical Co.[5]		
25 g - $9.35	5 g - $8.00 100 g - $23.60 1 kg - $121.40	N/A	5 g - $17.28 25 g - $46.10	N/A

*Chemical Supply Company, 1992 catalog prices
**N/A = not available
[1]ICN, 3300 Hyland Ave., Costa Mesa, CA 92626
[2]Sigma, P.O. Box 14508, St. Louis, MO 63178, Phone:(800) 325-3010, FAX:(800) 883-1576
[3]Research Organics, 4353 East 49th Street, Cleveland, OH 44125, Phone:(800) 321-0570, FAX:(216) 883-1576
[4]U.S. Biochemical, P.O. Box 22400, Cleveland, OH 44122, Phone:(800) 321-9322
[5]Aldrich Chemical Co., 1001 W. Saint Paul, Milwaukee, WI 53233, Phone:(800) 558-9160

Table 2. Comparative costs of indolebutyric acid, naphthaleneacetic acid, and their potassium salts.

Chemcial	Cost ($) Acid	Cost ($) Salt
IBA	6.75/5 g	420/500 g
KIBA	11.85/5 g	595/500 g
NAA	7.95/5 g	198/1000 g
KNAA	10.50/25 g	276/1000 g

a 5% error for NAA unless these numbers are factored into the process. To calculate the quantity of 97% IBA to be added to 1 liter of solvent to obtain 10,000 ppm IBA, divide 100 by 97 and then multiply this by 10 g (10.31 g).

FORMULATIONS

Liquid and Talc Formulations. The liquid and talc formulations currently available from United States and European companies are listed in Table 3. The newest, easy-to-use product is the Rhizopon-AA soluble tablet. (Available from Hortus USA Corp., 245 West 24th St., New York, NY 10011-1717, 212-929-0927). It looks like a giant brownish aspirin, weighs 250 mg and is 20% IBA. The actual IBA is 50 mg per tablet. Theoretically dissolve 20 tablets in a liter of solvent to produce a resultant 1,000 ppm IBA solution. Note, the tablets are made from the acid form of IBA and to produce more concentrated solutions, a solvent like alcohol must be used.

Table 3. Root-promoting talc and liquid formulations.

Talcs/tablet	Liquid
Rhizopon AA soluble tablets	Woods Rooting Compound
Hormex 1, 2, 3, 8, 16, 30, 45	Dip 'N Grow
Hormo-Root A, B, C, 1, 2, 3, 4	C-Mone
Hormodin 1, 2, 3	Stim-Root (Canadian)
Plantabbs rooting powder	Synergol (European)
Ferti-lome rooting powder	
Grow more rapid root	
Security clip and dip rooting compound	
Rootone F	
Seradix (European)	

In the United States, I found only three commercially available liquid formulations (Table 3). Dip 'N Grow and Woods Rooting Compound are well known to most propagators. They consist of approximately 1.0% IBA and 0.5% NAA in various solvents. C-Mone is available from Coor Farm Supply Service, Inc., Smithfield, North Carolina 27577 (800-999-4573). There are a number of formulations,

including K-salts, available from Coor. To date, Coor Farm Supply is the only company in the United Stated offering KIBA formulations.

Table 4. The relative weight in grams of IBA, KIBA, NAA, and KNAA (average of 5 weights).

	1/2 teaspoon	1 teaspoon	1 tablespoon
IBA	0.71	1.61	4.36
KIBA	0.80	1.55	4.85
NAA	0.53	1.00	2.93
KNAA	0.45	0.96	3.04

Preparation of IBA and NAA Formulations. I weighed level 1/2 teaspoon, teaspoon, and a tablespoon of "pure" forms of IBA, NAA, and the K-salts (Table 4). The differences were enormous, particularly between IBA and NAA. Weigh as accurately as possible when mixing the chemicals to produce a liquid or talc formulation. Do not accept volumetric measurements as representative of a given weight. For absolute precision, weigh with a gram scale and use metric volumetric vessels.

For realistic purposes and sanity maintenance, weigh 5 g of the chemical and add to one pint of solvent to obtain 10,000 ppm or 1.0% stock solutions. Ten grams to a quart of solvent produces the same results.

The solvents most commonly used are water for the K-salts and alcohol for acids. Carriers or penetrants including DMSO (dimethyl sulfoxide) have been used but are no longer included in commercial formulations. Woods Rooting Compound will no longer include dimethyl formamide (DMF).

Table 5. Dilution rates for producing 1,000, 3,000, and 5,000 ppm IBA solutions from 10,000 ppm IBA stock solution.

Desired concentration	Stock (10,000 ppm IBA)	Solvent (dilutant)
1,000 ppm IBA	1 part (10 ml)*	9 parts (90 ml)
3,000 ppm IBA	3 parts (30 ml)	7 parts (70 ml)
5,000 ppm IBA	1 part (50 ml)	1 part (50 ml)

*Represents the volume in milliliters (ml) assuming a 100-ml graduated cylinder is used. For a 500-ml graduated cylinder use 5 times the amount listed; 1,000-ml graduated cylinder use 10 times the amount listed.

Much has been written about the use of propylene glycol and polyethylene glycol; however, their overall efficacy is still unclear (Barnes, 1988; Barnes, 1989; Dirr , 1989). If the data are intensely scrutinized, their use appears beneficial for extremely difficult-to-root species and species that are sensitive to alcohol.

Once the concentrated stock solutions are made, it is easy to produce lower concentration solutions by simple dilution with the appropriate solvent. Use 100-, 500-, and 1000-ml graduated cylinders to facilitate the process (Table 5). For most softwood cuttings, 1,000 to 3,000 ppm is the concentration range of choice. Use 5,000 ppm for firmer-wooded, late season cuttings and 10,000 ppm for extremely difficult species.

IBA and NAA can be dissolved or mixed together. Most commercial liquid formulations use a ratio of 2 : 1, IBA : NAA. I estimate that 3 : 1 or 4 : 1 are probably as effective. Experimentation is worthwhile, and the solutions permit quick and accurate mixing and dilution.

For mixing talc formulations the reader should refer to Machen (1977).

Always, when using liquid or talc preparations, decant a small volume or weigh and never return it to the stock solution. Common sense also dictates the use of rubber or plastic gloves. No matter what chemical, protect yourself and workers from undue exposure. The superiority and easy-to-handle nature of liquid formulations make them the product of choice for the commercial propagator.

Always learn all you can about new products and their claimed effectiveness, but remember that IBA and NAA have been the mainstays of our industry for over 57 years.

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Fog Propagation of Rhododendron Using Bottom Heat

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Buds & Blooms is starting its 10th anniversary of growing and specializing in ericaceous plants. We also grow crapemyrtles, roses, pansies, and mums. We produce more than 300,000 plants annually on approximately 20 acres. About 80,000 of these are rhododendrons. We have used forced-air bottom heat for rooting rhododendrons from the start of the nursery. We chose this method because it was by far the cheapest method I knew of supplying bottom heat, and it is effective. We began using fog and fog in combination with mist for propagation in 1988 and feel it has improved our rooting percentage.

Our propagation houses are 14- × 96-ft double-poly quonset houses. They are vented with 24-in. exhaust fans and have 37-in. × 63-in. intake shutters that are thermostatically controlled. The houses are heated with 130,000 BTU Modine fan or blower-type gas-fired heaters. Two of our propagation houses have benches with bottom heat that can be used for propagation of rhododendrons.

Our benches are made of treated 2 × 4s and 2 × 6s with snow fencing on top. These frame benches are set on top of concrete blocks, which are standing up on end. A curtain of 6-ml poly is draped around the perimeter of the benches to hold in heat and force it upward towards the cuttings. The 130,000 BTU Modine Heaters supply bottom heat. The heaters have been retrofitted with a Y adapter to supply heat under each bench. To each side of the Y adapter we attach a poly ventilation tube prepunched at 10 o'clock and 2 o'clock to distribute the heat as evenly as possible under the benches.

We use a well-drained propagation medium that we blend ourselves, incorporating only lime. We do not incorporate fertilizer due to the length of time it takes rhododendrons to root. Incorporated fertilizer can easily burn off the roots as they begin to initiate. Our soil mix components and percentages are shown in Figure 1.

We begin taking rhododendron cuttings in mid to late-November after the last flush of growth is well hardened off but preferably before any extremely cold weather begins. We also wait until we finish winterizing and covering all of our poly houses, which can be as late as the first of December.

We take cuttings from the last flush of growth. We make the cut down to the next whorl of leaves to avoid leaving a stem that might get infected by disease. If the plant is a little leggy, we may make another cutting below the first, although rooting percentage may not be as good with the second. In some cases the last flush of growth may be a multiple flush due to pinching. In this case you can take any or all of these cuttings. These cuttings are probably the most desirable and tend to root the best. They are usually about the thickness of a pencil or a little smaller. Cuttings that are very large do not root as well as the smaller ones. Since we take rhododendron cuttings after the growing season, we can only take these cuttings from our one-year 3-gal plants that will be grown on for another year.

After taking the cuttings we bring them back to the heated shop area where they are prepared for sticking. The cuttings are cut to approximately 3 in. with a grafting

or budding knife, making this bottom cut at a 45 degree angle. We also remove all but 3 to 5 leaves depending on their size. If the leaves are very large and broad, we cut them by one-third to one-half to reduce transpiration. Next, the cuttings are wounded on either or both sides for a large cutting or one side for smaller cuttings. We no longer soak the cuttings in a fungicide solution such as captan or Benlate and have not seen any adverse result due to this change. At this time of the year it is cold and hard to dip cuttings.

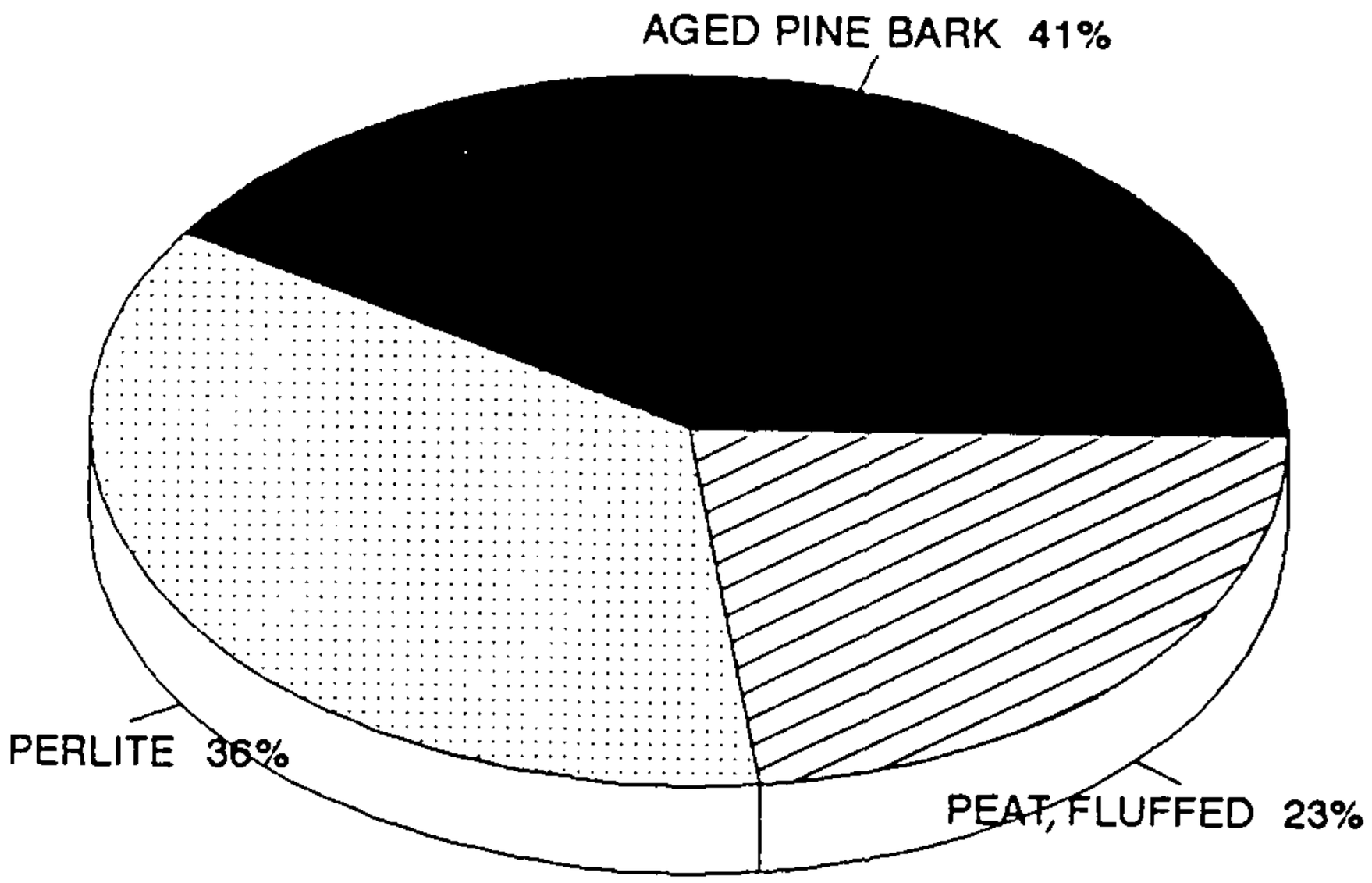

Figure 1. Propagation medium.

Our next step is to dip the cuttings in rooting hormone for approximately 5 sec. We have tried both the liquid and talc forms and various concentrations of different rooting hormones. We have found that a liquid combination of both KIBA and NAA gives us the best results. We use C-Mone K-Plus produced by Coor Farm Supply in Smithfield, North Carolina. This solution comes ready to use at 10,000 ppm KIBA and 5,000 ppm NAA or can be diluted for easier-to-root plants. To keep things simple, we use this formula for all of our cuttings. However, some cultivars of rhododendron that are very hard to root may take higher concentrations of hormones to root as well as the easier-to-root cultivars, so we are experimenting with 20,000 ppm KIBA and 5,000 ppm NAA. At this time we choose to buy liners of some of the hardest to root cultivars such as 'Scintillation' and 'Bessie Howells', rather than take up space in our propagation houses with cuttings that may root poorly.

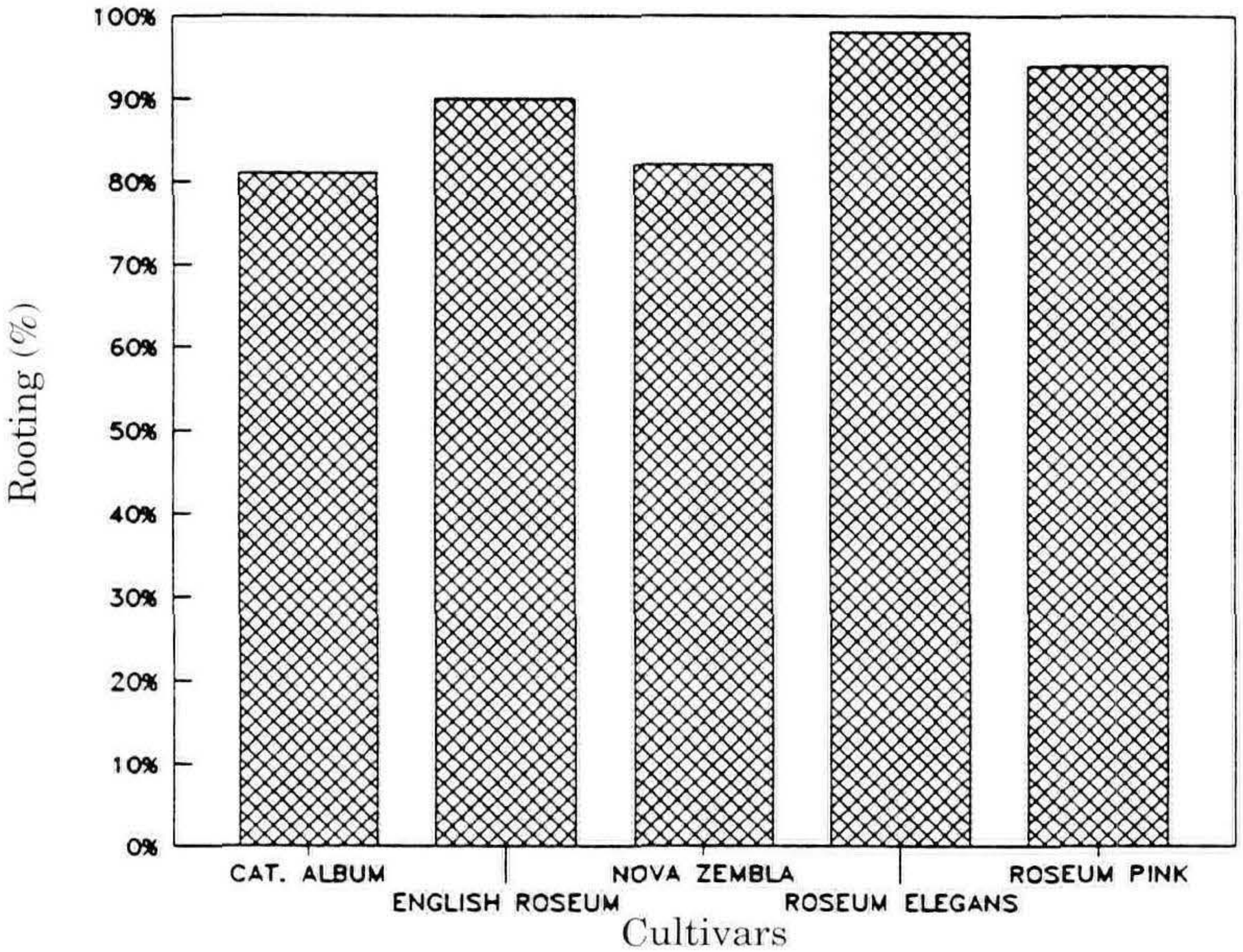

Figure 2. Rooting percent of five rhododendron cultivars using the system described in the text.

The cuttings are then direct stuck in 2¼-in. or 3-in. pots on raised heated benches and placed in either a fog house or a fog-mist combination house to begin rooting. I prefer the fog-mist combination as it is easier to control. We find dry spots with just fog. The thermostat for the bottom heat is soil controlled by a soil probe set at 70°F. We use bromine in line to control algae and perhaps help with disease. The rooting process starts with callusing, which can begin within a few weeks; however, it generally takes 8 to 12 weeks or longer for the cuttings to begin rooting profusely. Any that are still just callused are thrown away.

Looking at the overall picture, this system has both its advantages and disadvantages. This type of bottom heat can cause some dry spots and is not as even as some other sources of bottom heat. It will also keep the greenhouse hotter than necessary in order to keep the soil temperature at approximately 70°F. On the other hand, it is a relatively inexpensive means of heat, and it works, as can be seen in Figure 2.

In conclusion, this system has worked well for me the past 9 years. Although we have made many changes over these years to help improve efficiency, productivity, and quality, we have not seen any reason to change the type of bottom heat we have been using. This is not to imply this is the best or right way, but it is our way of propagating rhododendrons and it seems to work quite well for us.

Dwarf Yaupon, Weeping Yaupon, and Azalea Propagation at Flowerwood Nursery, Inc.

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AZALEA PROPAGATION

We begin taking our cuttings in spring, after the first flush of new growth has hardened off to where a stem snaps when bent. This is usually in mid-May. We start with the more difficult cultivars. The earlier we can start with a good cutting the better. Our rooting percentage is best if we can get roots before extreme summer heat.

In addition to all native azaleas, some azalea cultivars I like to start with are: Snow, Christmas Cheer, Hinodegiri, Delaware Valley White, Hino Crimson, and Mother's Day.

We take spring cuttings of all hardy cultivars of Kurumes, Glendales, Girards, Satsuki and similar azaleas, and less hardy but slower-growing cultivars like Red Ruffles. We also take spring cuttings of indica-like cultivars such as Kate Arendall, Jennifer, and Amy that tend not to grow well with the indicas.

We take 3- to 4-in. cuttings from healthy plants with good nutrition levels. Avoid cuttings that are too fat or too thin, as the fatter ones tend not to root as fast and the thin ones are more susceptible to stem-rot disease. If they are not too tender to stand up, we leave the tops on the cuttings as this helps the cuttings root faster. If the tops are very tender, we remove them but still finish with a 3-in. cutting.

The cuttings are immersed in a captan fungicidal bath for about 10 min. These cuttings are then spread out on a table, tender tops removed, and bottom end leveled. Basal ends are dipped for 3 sec in 3000 ppm KIBA. I use 5000 ppm KIBA on more difficult cultivars or harder cuttings. These cutting are put in buckets until ready to be stuck. Any cuttings left unattended on the table are misted once every 20 min with Flora-Mist nozzles.

After the cuttings are prepared, they are taken to our rooting area to be stuck in our rooting mix which consists of the following: 3 bark : 2 peat : 3 perlite (by volume). We add the following to each cubic yard of mix: 1½ lb Micromax, 6 lb 18-6-12 Osmocote, 2½ lb dolomite, 2½ lb oyster shell lime, and 1 lb granular Dursban. This mix is used for all plants except blueberries. It is an excellent mix for direct rooting. It is loose enough that it does not hold too much water yet retains enough to grow liners. For azaleas we fill this into SR-325 pots from Lerio.

We root under intermittent mist, starting at 7:30 a.m. and stopping at 6:30 p.m. The cycle is adjusted during the day so that cuttings are misted when approximately 85% of the leaf surface is dry. At the onset we mist heavier to get the cuttings over the shock of being taken from the container plant. Usually we reduce the water-cycling time as soon as the tender tops do not droop. We use a Rain Bird MIC-8 controller clock for mist control. This clock gives great versatility for misting and watering. A sample of a misting cycle would be as follows:

7:00	a.m.	to	8:30	a.m.	10 sec every 30 min
8:30	a.m.	to	11:00	a.m.	10 sec every 15 min

11:00	a.m.	to	3:00	p.m.	10 sec every 10 min
3:00	p.m.	to	5:00	p.m.	10 sec every 15 min
5:00	p.m.	to	6:30	p.m.	10 sec every 20 min

We root in a large plastic-covered, gutter-connected house under 51% shade cloth, and with the side walls vented but shaded. At this time of year rooting under plastic can be tricky. The plastic tops give us better control over the weather. We can eliminate rain problems on the cuttings and modify the temperature. Early rooting under this type of structure is a must. Once the days get too warm, the covered greenhouses heat to a point that can stifle rooting. We gradually remove sections of poly from areas where cuttings have rooted to allow excess heat to vent out of the roof. I only remove this poly from more root-hardy cultivars and make sure more sensitive cultivars are well rooted before I take off the top.

After everything is rooted, we remove all the plastic and grow them on. By late summer I also remove the shade cloth to harden them up and acclimate them to outside conditions. In early September I move the entire crop outside to full sun in a holding area.

Our first trimming usually takes place in July on faster cultivars and in August on slower cultivars. We trim twice more in September, finishing by October 1.

We start to fertilize with 12-6-6 as roots appear and do this every three weeks until October 1. The liner will continue to grow until the end of October. By then cooler nights and lower fertility slow the growth and allow the plants to harden off for winter.

If we have an early freeze, our liners are covered with frost-protective cloth to stop cold damage. If we have an early frost, we watch the temperature. If frost starts to form, usually about 5:00 a.m. we wash it off. Usually one washing is enough, but it may need to be repeated until the temperature rises. This only works for frost, not for a freeze.

In December the liners are planted into larger containers for production. These are protected as needed until about February 15th when the extreme weather has usually passed. Indica azalea cuttings are taken in September. We use a similar method except that they are initially not covered. We cover our houses in late October, and we finish off the rooting under this top. Indicas are left inside all winter and only heated to prevent freezing. We set our thermostats on 40°F.

Indicas usually root rapidly with very few losses. We dip our cuttings in 3,000 ppm KIBA. They will root well without any hormone treatment, but rooting uniformity is better if we use a hormone dip.

After all the cuttings are rooted and the water has been cut off, I apply fertilizer once if it is earlier than Thanksgiving. After that date I will not apply any more until late February or early March after the liners bloom. During the period between December and March the 6 lb of 18-6-12 Osmocote in the soil mix provide enough fertility to keep the cuttings healthy. From March to April, we apply 12-6-6 every three weeks and have a plantable liner by April 15.

WEEPING YAUPON AND DWARF YAUPON PROPAGATION

At the Mobile location, I generally plan to put in all cultivars of yaupon in the early fall. This fits my schedule well. Although we can root them well in the summer, I prefer the fall because there is less stress on the cutting. Yaupon roots best for me

if I can maintain good humidity around the cutting because the leaves hold very little water without frequent, and sometimes too much, mist.

I try to start cutting by the last week in September and finish in about three weeks. We usually stick about 400,000 liner pots of dwarf yaupon and about 10,000 weeping yaupon each year.

Ideally, we like a cutting that is hardened-off current season's wood. The basal end should be gray. We like to take our cuttings from well-fed containerized plants. Rooting percentage is much better than for cuttings from field plants. Even well-nourished field plants usually don't root as well as cuttings from containers.

We never let our cuttings get stressed after they are taken. We take all of our cuttings in the cooler morning hours. We pick up the filled cutting buckets frequently and take them to our stripping shed for preparation. They are spread out on the table under mist until they are prepared for sticking.

The weeping and other native yaupon cultivars are cut before the dwarf yaupon. They take longer to root, so we try to put them in first. We take a branched cutting to get as much leaf surface as possible, usually about 4 inches long. We then strip wound the bottom by tearing off the lowest branch. This practice seems to work better than wounding with a knife. The cuttings are dipped in 1,870 ppm IBA for 3 sec and are placed in a 15-gal container until ready to be stuck. I believe other hormone treatments may work but this particular strength has worked well for us. One note of caution, never use NAA on yaupon. This hormone will burn the stem and cause the cutting to defoliate. We stick yaupon in the same rooting mix that we use for azaleas. The cutting are stuck ½ in. deep in a 2¼-in. rose pot.

One problem I have with weeping yaupon more than other cultivars is stem rot. This may be because this cultivar is slow to root. Often, slight callus formation is the only early response. To help counteract any stem rot, I broadcast Agri-Strep on the planting beds. I mix one tablespoon to a gallon of sand and broadcast 1 lb per 100 sq ft.

After sticking weeping and native yaupon cultivars, I stick dwarf yaupon, *Ilex vomitoria* 'Schillings'. We take a branched cutting about 3 in. long at the point where the summer wood has begun to turn gray. If possible, we leave a branch on the cutting about 1/4 in. above the base to keep the cutting from being stuck too deep. Dwarf yaupon responds better to rooting than the native types. I've had roots develop in as little as 2 weeks, but 4 weeks is more usual. Swelling and callus formation occur earlier. As the weather cools, rooting response slows; and we may not cut our mist off totally until February on the last cuttings. The clock we use for rooting yaupon is a Rain Bird MIC-8 controller. The first cuttings are stuck before our plastic has been put on the greenhouse, so we mist more heavily. Our first schedule may be as follows:

7:30	a.m.	to	9:00	a.m.	10 sec every 20 min
9:00	a.m.	to	10:30	a.m.	10 sec every 15 min
10:30	a.m.	to	12:00	p.m.	10 sec every 10 min
12:00	p.m.	to	2:00	p.m.	10 sec every 7 min
2:00	p.m.	to	3:00	p.m.	10 sec every 10 min

When the house is covered, we can lighten up in the morning and evening, but we still need to use frequent misting in the middle of the day as the temperature gets higher than we like.

All yaupon are relatively easy to keep free of disease. Red spider mites and leaf miners can cause great problems. Under greenhouse conditions mites are always a potential problem but can easily controlled with a regular spray program. We use Vendex, Mavrik, and Avid as miticides. To control leaf miners I use Metasystox-R. This will kill the miners, but it is a strong chemical. Be sure to treat the cuttings after work when the house is clear. The best control is to control the flying insects that cause the problem by laying the eggs. However, this pest is not often seen.

Yaupon will start to grow naturally inside in early March. At this time, I fertilize with 12-6-6 every three to four weeks. By May, I have a nice plantable liner.

Propagation of Japanese Maples by Softwood Cutting and Grafting

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METHODS OF PROPAGATION

At Greenleaf Nursery in Park Hill, Oklahoma, we use two main methods of propagating Japanese maples (*Acer palmatum*), softwood cuttings and grafting. Although we are constantly experimenting with new techniques, the basic ideas remain the same.

We grow four main cultivars: 'Bloodgood', 'Oshio-beni', 'Ever Red', and 'Viridis'. Only two of these, 'Bloodgood' and 'Oshio-beni', produce a good enough root system to suit our needs when they are grown on their own roots. The other two cultivars are grafted because they root poorly and develop weak root systems when they do root.

SOFTWOOD CUTTINGS

The cuttings for 'Bloodgood' and 'Oshio-beni' are taken when the new spring growth hardens, usually early June in our area. Approximately 6-in. cuttings are taken, and all but the last two leaves are stripped. We wound both sides of the stem, and the base is quick-dipped in an 1,800 ppm solution of IBA. The cuttings are then stuck in a 1 sand : 1 pine bark (v/v) mix. Mist is applied about every 15 min as weather conditions warrant.

In the fall the rooted cuttings are dug, potted in a pint pot, and placed in a quonset for overwintering. The quonset thermostat is set at 35°F to allow cuttings to become dormant but not freeze. The following spring, after the danger of frost, these Japanese maples are shifted into 3-gal containers and grown for three more years.

GRAFTING

Grafting is the principal method of propagating the Japanese maples. A successful grafting program depends first of all on good understock.

Producing Japanese Maple Understock. To produce your own understock, you usually must buy seed from a commercial seed dealer. This is not a problem, but you might want to keep in mind that first, in my opinion, green-leaved types are a little more vigorous than the red-leaved types. Therefore, I like to use the green ones for understock. The red-leaved understock can be grown on just as a seedling. Some of these red seedlings can be outstanding and make excellent landscape material.

Another thing to remember is that seed dealers generally handle seed that has been dried so it can be stored. If you plant this dried seed directly in a flat or seed bed, you will get about 5% germination the first year, 25% the second year, and scattered germination for the next several years. To prevent this problem, plant fresh seed or soak the dried seed in water that starts at 120°F. Allow water to cool slowly. This soaking should last 24 to 48 h. Whether you use fresh or dried seed, it must be stratified for 60 to 120 days before planting.

Plant the maple seed about ¼ to ½ in. deep. If everything cooperates, you should have usable understock by that fall. I like to use one-year seedlings with a caliper of 3/16 to ¼ inch.

Get Ready to Graft. Finally, in early to mid-January we are close to the time to start grafting. Approximately 2 weeks before you want to start grafting, dig and pot the understock and place plants in a greenhouse with a temperature of about 65°F When the buds start swelling but have not produced leaves, GRAFT! Do not wait. Timing is very critical. If you delay until the leaves form, the understock will be producing too much sap and the percentage take will drop significantly. I have been told by people in Oregon that they do their potting and grafting at the same time.

Grafting Technique. At Greenleaf, the method we use is a side graft, just like a juniper graft. The understock is just starting to grow and the scion is totally dormant. We use a 6-in. scion, and shape the base of the stem into a wedge by making a 1 to 1½- in. cut on both sides. It is very important to use an extremely sharp knife when doing any cutting on Japanese maples. This prevents bruising of the cambium. We use a utility knife that has replaceable razor blades for a cutting edge. Next make a slice into the base of the understock that is just slightly longer than the cut on the scion. Carefully slip the scion into the under stock and wrap the union with a grafting rubber. The cambiums must match on at least one side. Then we use a graft-sealing paint to cover the wound at the top of the scion.

Now, the freshly grafted plants are rushed into a greenhouse that has bottom heat. They are placed on the bench, and fine ground, moist pine bark is placed around the union. The pot temperature is maintained at 70°F. The pine bark is misted when it starts to dry out on top. When the union is well callused and the scion is vigorously growing, the understock above the graft can be cut off. Sunlight will break down grafting rubber, and it will fall off.

SUMMARY

There are undoubtedly as many different methods of propagating Japanese maples as there are different propagators. These are the methods we use at Greenleaf Nursery. Just remember that you must have good understock, good scion material, good technique, and good timing for a successful program.

Propagation of *Nandina domestica* Cultivars at Tawakoni Plant Farm

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All cultivars of *Nandina domestica* are propagated by semihardwood cuttings, except the purchased tissue-culture 'Harbor Dwarf' cultivar. The low yield of cuttings of 'Harbor Dwarf' makes cutting propagation impractical.

Nandina propagation is not very difficult; however, as in any propagation procedure attention to detail can make the difference between success and failure. Prior to propagation the beds and walks are sprayed with a 16 to 1 solution of water and bleach. The mist nozzles are cleaned and checked for coverage. Further prevention of pathogens is provided by a chlorine gas injection system at the propagation pumphouse.

Nandina cuttings are collected from container plants and field-grown stock plants in October. The cuttings are then submerged in a captan solution and cut to a length of 2½ to 3 in. with terminal shoots removed. The wood should be reddish, and from current season's growth. We remove lower leaves, leaving the two terminal leaflets. On some of the larger-leaved nandinas it may be necessary to cut the leaflets back. The basal end of the cuttings are quick dipped in a 3,000 ppm IBA (indolebutyric acid).

The nandina cuttings are then direct stuck one per pot in prefilled 2¼-in. rose pots in a 30- × 96-foot polyhouse covered with 55% shade. The medium is 7½ fine pine bark : 3 medium perlite : 2 peat moss : 1 sharp sand (by volume) with triple superphosphate, dolomitic lime, and other micronutrients. Cuttings are put under intermittent mist of 2- to 4-sec duration at 6- to 8-min intervals for the first 10 days. Misting intervals are gradually increased until cuttings are rooted.

A bottom heat system is used under the cuttings with the temperature maintained at 75°F. The bottom heat system consists of a swimming pool heater and a pump circulating water through a 2-in. PVC manifold with 16-mm lateral lines spaced 6 in. apart under a 3-in. sandbed.

Cuttings stuck in October are ready to plant in 1- or 2- gal containers by March of the following year. The plants are ready for sale about one year from the sticking date.

Use of Composts in Nursery Potting Substrates

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Cultural practices in container nurseries in the Southeastern United States have evolved to frequent irrigation, porous substrates, and slow-release fertilizers. This combination results in rapid plant growth with few problems. However, water quality, solid waste, and fire ants may soon bring changes in irrigation and potting-substrate practices. Substrates such as pine bark and sand have low anion and cation exchange capacities, and nutrients available for plant absorption are primarily held in solution between particles. Overhead irrigation pushes water and nutrients in solution out of the pot; therefore, irrigation can affect water quality in the environment.

Solid waste management of urban yard wastes and agricultural animal wastes have become environmental concerns in the United States, and composted wastes are being targeted for use in the nursery industry as potting components. The usefulness of these composts to the nursery industry needs to be evaluated.

Most recently the amount of Talstar required for fire ant suppression is based on the weight of the substrate. Southeastern growers who must use Talstar may use less sand in order to reduce bulk density, which determines the weight of the substrate. Water quality control and solid waste management may also create widespread changes in potting substrate in the Southeastern United States.

Table 1. Percent solids, drainage and bulk density of pine bark and pine bark : sand substrates.

Substrates	Solids[x] (%vol)	Drainage[y] (ml)	Bulk density[z] (g/cc)
PB[w]	16.22	70.4 a	0.19 c
9PB:1S	24.84	39.2 b	0.38 b
5PB:1S	33.77	12.2 c	0.69 a

[x] Solids = The total % volume of solids in each medium.
[y] Drainage = Amount (ml) water drained from each cylinder after saturation.
[z] Grams per cubic centimeter after drying samples in a forced-air drying oven at 110°C for 24 hours.
[w] PB = pine bark, S = sand.

The addition of sand (S) to pine bark (PB) adds weight which, growers appreciate because larger plants blow over less when potted in a heavier potting substrate (Table 1). Sand also fills in between bark particles which reduces total pore space, but mostly affects the air space of potting substrates (Table 2). However, unsaturated (lateral) flow and infiltration rate are not often measured in potting substrates. Sand drastically affects these physical properties. For example in Table 1,

drainage values for three substrates are shown. As the volume of sand is increased from 0% to 10% and 17% by volume, drainage values 15 min after saturation decreased nearly two and six times. In a nursery, decreased or slower drainage would allow irrigation water to wet the substrate rather than channel rapidly through the container. Vertical water movement is fast but horizontal movement is slow in 100% pine bark. The addition of sand slows capillary water movement downward and, therefore, increases water movement across the container. If nurserymen reduce the amount of sand to reduce weight, then either irrigation practices need to be adjusted or other components added to enhance lateral water flow in pine bark. Ultimately, these new components will substitute water retention for the weight of the sand. The number of possible available components is almost unlimited. However, many are unstable, inconsistent, and hard to reproduce. Often supplies are limited, shipping and handling costs are high. Other than peat moss, which is familiar to most nurserymen, potential components need to be locally available to reduce shipping costs.

Table 2. Physical properties of substrates.

Media[x]	TP[w]	AS[v] (% Volume)	CC[u]	UAW[t]	AWC[s]	BD[r]
PB	83.70 c[z]	18.45 a	65.22 ab	31.92 b	33.30 c	0.19 c
PB+CYW (90 : 10)	81.42 c	20.60 a	60.82 c	30.18 c	30.64 c	0.23 bc
PB+TBL (90 : 10)	85.28 ab	18.24 a	67.04 a	33.97 a	33.07 c	0.20 c
PB+RW+CYW (70 : 20 : 10)	84.78 bc	16.98 a	67.80 a	27.35 d	40.45 a	0.24 b
PB+RW+TBL (70 : 20 : 10)	86.08 a	18.07 a	68.00 a	28.42 d	39.58 b	0.22 bc
PB+S (80 : 20)	76.62 d	10.94 b	65.68 b	24.58 e	41.10 a	0.45 a

[z] Mean separation in columns by Waller-Duncan k-ratio t-test (k-ratio=100), P=0.05. Analyses performed using aluminum soil-sampling cylinders (7.6 cm i.d., 7.6 cm h).
[x] PB = pine bark, CYW = composted yard waste, TBL = turkey broiler litter, RW = granulated rockwool, S = sand.
[w] Total porosity is equal to container capacity + air space.
[v] Air space equals water drained from the sample divided by volume of the sample.
[u] Container capacity was (wet weight-dry weight) divided by volume.
[t] Percent volume at 1.5 MPa.
[s] Calculated as the difference between container capacity and unavailable water.
[r] Grams per cubic centimeter after drying samples in a forced-air drying oven at 110°C for 24 h.

EPA has mandated solid waste reduction in landfills. As a result composts made up of a broad group of components will be available in most communities of the

United States. This paper will review results of studies conducted with turkey broiler litter (TBL) and yard-waste composts (CYW) as components in container potting substrates.

Bilderback and Warren (1992) reported increased bulk density, total porosity, and air space with incremental addition of a two-year-old TBL compost to pine bark. A 15% by volume compost amendment increased available water capacity, but additional TBL compost decreased the available water held in the substrate. Electrical conductivity (soluble salts), nutrient leachate concentration, and foliar nutrient content increased with incremental TBL compost addition. *Cotoneaster dammeri* 'Skogholm' top dry weight and root dry weight increased with 15% and 30% volume additions of compost but decreased with higher rates. 'Sunglow' azalea top dry weight decreased with incremental compost addition. However, data indicated that 15% by volume addition of TBL compost to pine bark resulted in physical and chemical properties that produced the best growth of cotoneaster.

Granulated horticultural rockwool (RW) appears to have properties that can increase air space when added to coarse pine bark substrates amended with composts (Bilderback and Fonteno, 1990).

TBL compost was added at 15%, 25%, and 33% by volume to pine bark or pine bark and horticultural rockwool substrates. The results of the study indicated that TBL compost blended with pine bark maintained higher phosphate and other nutrient levels during the growing season in substrates and plant tissue than pine bark alone, while rockwool increased air space when compost was used. Use of both components with pine bark produced growth equal to the pine bark control substrate for *Cotoneaster dammeri* 'Skogholm' and suggested that these materials could be beneficial in commercial nursery potting substrates.

However, negative effects of TBL included reduced air space and available water and excessive initial soluble salts. Further studies are needed to establish component ratios that will help solve these problems.

Work with a third source of TBL compost incorporated at 10% by volume produced physical and chemical properties similar to pine bark except that total porosity (TP) was increased and unavailable water content (UAW) was highest of the five substrates compared (Table 2). The addition of CYW 10% by volume to pine bark changed only container capacity (CC), which was least in the pine bark : CYW substrate. An 8 pine bark : 2 sand (v/v) substrate had the lowest total porosity, air space, and lowest unavailable water content and highest available water capacity (AWC) of the substrates compared. Addition of horticultural rockwool decreased unavailable water content in three-component substrates compared to two-component or pine bark alone. Of the physical properties tested, the three-component substrates appeared to have the most consistent favorable physical properties.

Electrical conductivity (soluble salts) and all nutrient leachate levels were measured by VTEM water-extraction procedure (Wright, 1986). All nutrient capacity factors were high on day 1 after potting in substrates containing TBL compost (data not presented). The PB : RW : TBL medium had an EC value of 4.5 dS•m-1 which was higher than all other treatments. High EC levels were apparently due to high leachate concentrations of NH_4-N, P, and K. Electrical conductivity was not significantly different on any other sampling dates. Leachate pH initially ranged from 4.9 to 6.1. During the study pH increased and all substrates ranged from 5.2 to 5.8.

Leachate phosphorus (P) level in substrates containing TBL compost were very high initially, generally 3 to 4 times greater than other substrates; however, the TBL substrates also maintained leachate P within suggested solution levels (Wright, 1986) through Day 42 (Table 3). Substrates without TBL were well below suggested levels by Day 42.

Table 3. Container leachate phosphate levels from 6 substrates on 5 sampling dates[z].

Substrate[y]	Sampling dates (days after potting)				
	1	22	42	63	84
Suggested leachate levels =10-15 mg/l	Phosphate leachate concentration (mg/l)				
PB	86.0 b[x]	11.8 c	2.3 c	0.7 c	1.2 c
PB+CYW (90 : 10)	66.3 b	7.5 c	1.9 c	0.97 c	1.5 c
PB+TBL (90 : 10)	330.3 a	78.5 a	16.8 a	8.9 a	8.9 a
PB+RW+CYW (70 : 20 : 10)	41.8 b	7.1 c	2.2 c	0.8 c	1.2 c
PB+RW+TBL (70 : 20 : 10)	376.5 a	43.1 b	9.3 b	2.2 bc	2.6 bc
PB+S	84.8 b	4.6 c	1.6 c	0.7 c	1.1 c

[z] Each value represents the mean of 6 containers.
[y] See Table 2 for abbreviations.
[x] See Table 2 for statistical methods.

TBL substrates had higher potassium (K) levels initially than other substrates with the PB : RW : TBL having 834 mg/l K while PB : TBL was 543 mg/l. However, all the substrates had relatively high K leachate concentrations with 201 mg/l K in the PB leachate. Leachate Ca levels were above 10 mg/l Ca throughout the growing season. Magnesium leachate values remained between 10 to 30 mg/l in VTEM leachate solution. After the first sampling date the PB : CYW substrates tended to be low in Mg.

Leachate Fe was similar for all treatments. A Zn : Fe interaction due to high Zn levels is sometimes a concern when composts are used in potting substrates. No problems were apparent in leachate or foliar data. Cadmium, lead, and nickel leachate levels were undetectable in all treatments of either species.

The greatest top dry weight of 'Skogholm' cotoneaster was greatest in the 7 PB : 2 RW : 1 TBL (by volume) substrate but this treatment was not significantly different from the 9 PB : 1 TBL (v/v) substrate (Table 4). The least growth occurred in the PB : S substrate. Root dry weights (not shown) were not significant among substrate treatments.

Cotoneaster tissue levels were from samples collected at the end the growing season. Most guidelines for foliar tissue nutrient levels are expressed as mid-

season optimal levels as given in Table 4 (Jones, 1991). Substrates containing TBL had foliar P level that would have been considered deficient by the guidelines.

Table 4. Effect of substrates on *Cotoneaster dammeri* 'Skogholm' foliar nutrient levels and top dry weight[z].

Container substrate[y]	Percents foliar tissue dry weight N	P	K	Ca	Mg	Top dry weight
PB	2.1 a[x]	0.06 c	1.03 a	1.04 c	0.45 ab	65.7 cd
PB+CYW (90 : 10)	2.1 a	0.08 bc	1.06 a	1.23 c	0.30 c	64.4 cd
PB+TBL (90 : 10)	1.5 b	0.15 a	0.99 a	1.70 a	0.34 c	90.5 ab
PB+RW+CYW (70 : 20 : 10)	1.6 b	0.10 b	0.87 b	1.55 ab	0.48 a	84.4 bc
PB+S (80 : 20)	2.3 a	0.06 c	0.98 a	1.08 c	0.48 a	50.6 d
Acceptable levels (Mid-season)	2.8	0.34	1.1	1.1	0.27	(g)

[z] Each value represents the mean of six plants.
[y] See Table 2 for abbreviations.
[x] See Table 2 for statistical methods.

Tissue nitrogen levels tended to be lowest in substrates containing TBL, which corresponds with leachate data that indicated greater solubility earlier in the year. Potassium and Ca foliar levels were generally within acceptable ranges. Although Mg solution levels in the PB : CYW and PB : TBL treatments were low throughout much of the study, the plants still had adequate Mg absorption. The foliar Ca data indicated the addition of the CYW and TBL yielded approximately equivalent foliar values as the dolomitic lime addition in non-compost treatments. Foliar tissue levels for Zn and Mn were not excessive and were not antagonistic with Fe in any treatment. Cadmium, lead, and nickel levels were below detectable limits for all treatments.

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New Herbicides for Ornamentals

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During the past few years several new herbicide products have been registered for use with landscape species. Changes have been made in the labelling of some of the older products. This manuscript includes an update of several of these changes.

Pendulum WDG (pendimethalin) is a recent registration from American Cyanamid Company. Pendulum WDG herbicide is recommended for preemergence control of annual grasses and small-seeded broadleaved weeds, including henbit, Florida pusley, prostrate spurge, and yellow woodsorrel. The area to be treated should be weed free at the time of treatment. Normal use rate is 2 to 4 lb ai/A, and weed control is most effective when application is followed with one-half inch of rainfall, or its equivalent, in sprinkler irrigation. This product is toxic to fish, and caution should be used in areas around water. Southern Weed Grass Control (pendimethalin) is a similar product in the granular formulation.

Pennant 5G (metolachlor) has undergone extensive expansion of the label by Ciba-Geigy. In addition to the broad listing of woody plants on the label there are about 55 annuals and perennials. Recommended use rate is 2 to 4 lb ai/A Pennant. Pennant provides control of many annual grasses, certain broadleaved weeds, and yellow nutsedge. Rainfall or irrigation equivalent to ¼ to ½ in. should be applied within one week of treatment. The Pennant Liquid Herbicide label and the Pennant 5G label now have parallel listings.

Derby 5G (metolachlor 4% + simazine 1%) is manufactured by Ciba-Geigy and has a broad label for nurseries and for landscape plantings. The recommended use rate for Derby is 2 to 4 lb ai/A and provides control of many annual grasses, certain broadleaf weeds, and yellow nutsedge. A second application may be needed to provide grass and yellow nutsedge control for an extended period.

Dow-Elanco has registered three herbicides in the past few years. Gallery 75 DF (isoxaben) was the first product registered. Gallery is a preemergence herbicide for control of certain broadleaf weeds in landscape ornamentals and nurseries. Gallery is best used in combination with another herbicide that provides good control of annual grasses (Surflan, Pendulum, Pennant). Gallery is stable on the soil surface for up to 22 days but does require rainfall or irrigation for activation (½ in.). The normal use rate is 1.0 to 1.33 lb of product per acre (0.75 to 1.0 lb ai/A). In a test at Auburn University, Gallery has provided similar weed control to other broadleaf herbicides on the market with greater ornamental safety.

The second product registered for ornamentals by Dow-Elanco was Snapshot 80 DF (oryzalin 60% + isoxaben 20%). This preemergence herbicide provides excellent control of many grass and broadleaved weed species when used at the recommended rate of 2.5 to 5.0 lb of product per acre (2 to 4 lb ai/A). Optimum weed control is obtained when Snapshot 80 DF is activated within 21 days of application with rainfall or irrigation. Snapshot 2.5 TG (trifluralin 2% + isoxaben 0.5%) was the third product registered for ornamentals by Dow-Elanco. This preemergence herbicide provides broad spectrum weed control for container-grown ornamentals, landscape ornamentals, ground covers, non-bearing fruit, and nut trees when

applied at the recommended rate of 100 to 200 lb product/A (2.5 to 5.0 lb ai/A). Application of Snapshot 2.5 TG to the wet foliage of certain container-grown species has not caused injury in several instances. Snapshot 2.5 TG has one of the broadest ornamental labels of current products on the market.

Sandoz Crop Protection Corporation has two new herbicides registered for ornamentals. Barricade 65 WDG (prodiamine) is a selective preemergence herbicide that provides residual control of many grasses and broadleaved weeds. For best results Barricade 65 WDG must be incorporated by rainfall, irrigation, or shallow cultivation. In our test this herbicide has shown excellent weed control and a wide range of safety to ornamental plants. Because of its formulation, use of Barricade 65 WDG is primarily limited to field use.

A second herbicide introduced by Sandoz is Predict (norflurazon). Predict is a soil-active preemergence herbicide for control of broadleaved weeds in field-grown nursery stock and non-croplands. For best results, activation of the herbicide is required within four weeks of application. When applied at the recommended use rate of 3 lb per acre (2.4 lb ai/A), Predict controls 24 broadleaved weeds and suppresses several others including nutsedge species. Predict has a limited label for ornamentals with 32 on the label. Predict should not be applied until the fall following the first full season of field growth after transplanting. In some of our tests, Predict has caused slight injury to some ornamentals (bleaching of older foliage at time of application) but has not resulted in reduced growth. Plants have grown past injury within 60 days after treatment.

BASF introduced Vantage (sethoxydim) for postemergence grass control in ornamentals. Vantage is a combination of Poast herbicide and a crop oil concentrate. This product greatly simplifies use by reducing the mixing process previously required. Vantage has a broad label for ornamentals including trees, shrubs, bedding plants, ground covers, and wildflowers. Vantage rapidly enters grass through the foliage and translocates throughout the plant. Control symptoms exhibited by the grass plant progress from a slowing of growth (generally within two days) to reddening of the foliage to leaf-tip burn. Subsequent burn back of the foliage occurs. This entire process may take up to three weeks. It is important to apply Vantage to actively growing grasses at the proper growth stage.

Another product recently registered for ornamentals by American Cyanamid Company is Image (imazaquin). It has a limited ornamental label but will provide control for some difficult-to-control weeds, especially the sedges. Image may be tank mixed with Surflan or pendimethalin to control weeds not controlled by Image alone. Image will effectively control susceptible weeds when applied during the recommended application times (pre- and post-emergence). Post-emergence control may require several weeks. Image applications should only be made to established plantings of the labeled ornamental. Temporary growth suppression may be observed on some treated plants. The label indicates severe injury occurs when Image is applied to azalea, viburnum, pieris, abelia, and ligustrum. In tests at Auburn University severe injury has occurred on dogwood, japanese holly, crapemyrtle, and juniper. Furthermore, growth suppression has occurred up to one year after the time of application. This herbicide provides excellent weed control but extreme caution is required to prevent or reduce injury to the ornamental.

With all pesticides used in and around nursery and landscape planting, it is important to use the product in a manner consistent with the label. Some labels

leave the door open for individual testing and use of the product. For example, the Snapshot 80 DF label contains the following: "Users who wish to use Snapshot 80 Dry Flowable on ornamental species of nonbearing fruit trees not listed on this label may determine the suitability for such uses by making trial applications of Snapshot 80 Dry Flowable on a small number of plants. The treatment should be observed for 3 to 6 months to determine if the treatment is safe to the target plant species." The user assumes the responsibility for any crop damage or other liability in this case. By reading the label closely, the user may avoid many problems both from a production and legal standpoint.

Chemicals Used During Propagation at Cottage Hill Nursery

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The liner division of Cottage Hill Nursery propagates woody ornamental species as well as a variety of annual and perennial crops.

The key to vegetative propagation is the propagator. Specific recommendations of rooting hormones are not enough to produce uniform stands of plants. The selection of cutting wood, handling technique, hormone rate, hormone application method, as well as propagation environment are the tools of the propagator. Success depends on how the cutting responds to the process of propagation.

Selection of hormone material and strength at Cottage Hill Nursery is carefully reviewed for every crop each time we begin its propagation.

We propagate over six million plants a year. The various market demands necessitate that some propagation houses have more than one cultivar and even more than one species, further complicating the propagation procedure.

The rooting characteristics of hollies vary widely. Mixing a house of hollies under intermittent mist demands the correct application of specific rooting hormone rates to optimize rooting uniformity. New growth of *Ilex crenata* cultivars is treated with hormone in the 0.3% IBA (indolebutyric acid) range and gradually scaled higher as winter approaches or after the wood has hardened. *Ilex cornuta* and hybrid holly cultivars are treated with a 0.5% IBA and 0.25% NAA (naphthaleneacetic acid) hormone rate, but can be treated with three to four times these rates depending on the cutting wood and prevailing environmental factors.

During the spring flushes of growth, azaleas can be propagated successfully using little or no hormone. Selecting the correct wood and intermittent-misting cycles are the dominant factors. At other times or when faced with substandard wood, rooting hormones applied at the rate of 0.3% IBA range increases rooting.

Poinsettia propagation is more uniform when 0.25% IBA is applied. However, using sanitary procedures and minimizing stresses are more important.

Finally, when a new line of plants has to be propagated, research and experimentation are essential. We began producing ×*Cupressocyparis leylandii* (Leyland cypress) using recommendations from books and other growers. In order to find the best procedure for our area (Mobile, Alabama), we took cuttings at different times of year and used different strengths of rooting hormones. We varied the cutting wood and rooting medium. We found we could propagate successfully any time by taking transition wood and using a 2% IBA and 1% NAA rooting hormone.

The proper and legal use of chemicals during propagation in most cases will enhance the rooting percentage and uniformity of vegetatively produced plants. However, the application of rooting hormones is not akin to magic, but it can be an essential tool of the professional propagator.

Use of Insecticidal Oils and Soaps for Pest Control

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Petroleum oils and soaps can be used on a variety of plants during all seasons of the year and are excellent alternatives to conventional pesticides for control of many soft-bodied arthropod pests. Such products are safer to workers and the environment, are not phytotoxic to most plant species, and do not induce resistance in the pest. This paper discusses the advantages and limitations of using oils and soaps.

DISCUSSION

Horticultural "petroleum" oils have been used for many years mainly as dormant applications to control a variety of insect pests. These dormant oils were not highly refined and were almost never used during the growing season because of the risk of phytotoxicity that resulted from the impurities included in the products. Also, cheap chemical pesticides that were extremely effective without the risk of phytotoxicity were the products of choice for pest control. Times have changed, and we now know that the use of many conventional pesticides is accompanied by adverse side effects. Water pollution, risk to workers, outbreaks of secondary pests, destruction of beneficial species and other nontarget organisms, and high costs, to name a few, have forced pest management practitioners and the nursery industry to seek alternative control methods. New, more highly refined insecticidal oils and soaps are attractive alternatives to conventional pesticides. In addition soaps and oils are safe to handle, which facilitates spot treatments or custom applications when appropriate.

Miller (1989) discussed in detail the characteristics of horticultural oils. Insecticidal oils are considered as either dormant or summer based on the volatility, unsulfonated residue rating, and viscosity. Phytotoxicity is directly related to the volatility defined as the distillation temperature. Summer oils are more volatile and have lower (around 412°F) distillation temperatures. The unsulfonated residue percentage indicates the purity and should exceed 90% for summer oils. Growers should read the label for the distillation point (volatility) and unsulfonated residue rating to determine the appropriate use for name-brand horticultural oils (Miller, 1989). There are many brands and types available for both summer and dormant use.

Miller (1989) also discussed in detail the characteristics of insecticidal soaps. These compounds are fatty acids derived from plant oils or animal fat. They also may cause phytotoxicity in plants under certain conditions. Some fatty acid soaps (different from insecticidal soaps) are used as herbicides. Soaps are not compatible with concentrated mineral elements, lime sulfur, Bordeaux mixture, copper sulfate, or rotenone (Miller, 1989).

Other papers not concerning soaps and oils not cited in the text are listed below for further information (see Literature Cited). These papers give many species of

plants that soaps and oils have been tested upon for phytotoxicity and control of specific pests.

MAJOR POINTS TO CONSIDER

The major points that should be considered by nursery growers when using soaps and oils are listed below.

1) Soaps and oils that are not labeled with EPA cannot be legally recommended for use as insecticides. Household products have many impurities that are not found in registered products and are not recommended.

2) Dormant oils and summer oils are different in terms of their risk of phytotoxicity.

3) Make sure plants of any species in containers or in the field are not under water stress when oils are applied. Phytotoxicity is related to plant water stress and may show up as a color change, browning, or spotting of leaves. Some junipers lose their dormant season coloration when treated with oil.

4) You can expect from 70 to 85% or better control of most aphids, mites, mealybugs, psyllids, scales, whiteflies, and some caterpillars using summer oil or soap sprays. No residual mortality will occur (repellency to certain insects may occur), only those pests directly contacted by the spray will be killed. Therefore, good coverage is important.

5) Neither soap nor oil sprays have the associated risk of resistance development in the pest species that is found in other pesticides.

6) You may mix horticultural oil and insecticidal soap together. The advantage is that oil suffocates and soap desiccates providing two modes of action and reportedly quicker pest mortality. The disadvantage is higher cost.

7) Oils or soaps when tank mixed with other pesticides often act as a synergist or adjuvant spreading the pesticide and increasing the penetration into the insect. Oils are compatible with most insecticides except carbaryl and dimethoate, but are not compatible with the fungicides captan and Karathane. Oils are fungicidal and decrease the incidence of some mechanically-transmitted viruses (Zinnen and Vachris, 1990). Soaps are not compatible with lime sulfur, copper, or rotenone products. Some soaps are algacides and also kill mosses and liverworts (Puritch, 1981).

8) If you are concerned about phytotoxicity to any plants from oil or soap, do a small plot test under the most extreme conditions you can envision using the products, before applying to large numbers of plants. Plant species that are grown in many cultivars, as for example, poinsettias, will differ in responses by cultivars.

9) Using soap or oil is strongly recommended whenever possible, particularly as preventative or prophylactic sprays when pest levels are low or unknown. Remember that the basis of any pest control program is to monitor plants for pests and apply pesticides when population levels warrant control. Save conventional pesticides for "silver bullet" needs. Oils and soaps are biodegradable, safer to workers, and do not induce pest resistance.

10) Oils and soaps cause less mortality to beneficial insects than most conventional pesticides, but they are not 100% safe. Oils are less selective than soaps. Predatory mites, eggs, and some immature stages of beneficial insects may be killed when covered by oil.

11) All the legally usable chemical tools remaining available to the industry should be managed effectively in some type of rotation. Whenever possible avoid using the same conventional pesticides repeatedly on successive pest generations.

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Safety Programs to Satisfy the Right-to-Know Laws

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The title of this paper may be misleading, as it implies that you just need to complete some sort of check list to comply with regulation. Unfortunately it is not that easy; safety awareness must first be introduced to your nursery. It starts at the top of your organization and is followed through by your supervisors and foremen. Without this approach, whatever programs you write on paper will be frustratingly difficult to enforce.

The Hazardous Communications Laws or Right-to-Know laws were written to reduce the possibility of chemically caused illnesses and injuries and to give physicians the information they need to diagnose and treat pesticide poisonings. By committing to follow the guidelines of the Hazcom Laws, your nursery is making a commitment to your employee health and welfare through education and continued safety awareness.

Where you live will dictate whether or not you are required to follow additional regulations in your state Hazcom Law, if it has one. All nurseries must comply with the Federal OSHA Hazardous Communication Act, (Nov. 1983) and in Texas, comply with the Texas Agricultural Hazard Communication Act, (Sept. 1988). Under the OSHA regulations, all nurseries are required to have a written Hazcom program. Your program should include outlines of your company's policy regarding the following:

1) Container labeling policy. It is the responsibility of the company to verify that chemical containers are properly labeled at the time of receiving from the manufacturer or distributor and to see that all other containers used on nursery for chemicals must also be labeled and have a hazard warning.

2) Inventory of hazardous materials. An up-to-date inventory of all chemicals used by your company and the location where exposure to the chemical is most common.

3) Material Safety Data Sheet (MSDS). Your company must keep a file of an MSDS for each type of chemical used or stored. It is your responsibility to get these if the manufacturer does not send one for each product.

4) Employee training. All employees must be familiar with the MSDS information, how to read warnings on labels, and what hazardous signs mean on your nursery. Employees who use chemicals should be trained and that training recorded.

5) Non-employees. Contractors and companies delivering hazardous chemicals should be made aware of hazardous areas and your policies and should also have access to MSDS sheets.

6) Respirator and other protective gear. OSHA has specific guidelines regarding the care and use of respirators. Other protective gear should be worn as recommended on the MSDS. It is also an OSHA regulation that persons who wear a respirator first have a pulmonary function test and be tested annually.

Once it is written and you have management 'signed off' on it, begin to get your supervisors and foreman-level employees involved in helping pull together and

review the information. From there, you will be able to see what specific areas must be targeted. No matter how comprehensive your nursery program, each department will have situations unique to it. Each department then should have written policies regarding those situations. It is well documented that most accidents come from new employees or employees borrowed out of other departments. Having department guidelines helps your supervisors and foreman remember to go over hazards and make new or borrowed employees accountable to that training. Document all training. This is your only protection in law suits, and once again it is a form of enforcement to make sure training is carried out.

In Texas we have additional regulations to follow under the Texas Department of Agricultural (TDA) Hazards Communication Act. At this time there is some difficulty in interpretation of those regulations as they pertain to nurseries. I would encourage working with your local TDA office to design a program for your facility.

These are the areas covered by the act (Texas Dept. Agr., 1988):

1) The employee has the right to have a designated representative in complaint situations.

2) Employers must have Materials Safety Data Sheets (MSDS) on file.

3) Employers must keep a work-place chemical list. The list would be a record of all chemical usage; the amount used, date used, location of use, and the crop treated. These records are to be stored at the nursery or TDA for 30 years.

4) TDA will provide crop sheets, which give information to employees on types of chemicals used in a nursery and other relevant information. These are supposed to be read to each employee. The policy regarding the use of crop sheets in a nursery situation is unclear. You should work with your local TDA person.

5) Employers must provide protective clothing, equipment, or devices as specified by the label, MSDS, or crop sheets.

6) Employers may not take any retaliatory action against employees who exercise rights under the act.

Maintaining safety awareness is not an easy task nor is covering these regulations. Management will find themselves taking a hard look at the types of chemicals and the volume of chemicals used at their nursery. IPM programs become more critical and meaningful. Here are some ideas you may consider when setting up your program:

- If you can afford it, consider hiring a safety consultant to help you get started. They're not as expensive as you might think.
- Start a safety committee made up of all departments from supervisory level on down.
- Have the committee inspect the nursery periodically.
- Look for unusual hazards such as acid injectors, cleaning tanks, and steam pipes.
- Target new employees. If you have a large nursery, make them wear a different colored hat or something until they are past orientation period. We have them wear an orange safety vest.
- Drift. Consider how your technical service department should handle this with field personnel.
- Consider what area you should quarantine after applying a pesticide. Coordinate irrigation with pesticide application.

- How long does your pesticide get to stay on the plants? How much more effective would chemicals be if they stayed on the plants longer?
- Document all accidents.
- Designate one person to order or sign off on purchase orders on all chemical orders. It is this person's responsibility to update MSDS.

And finally, make it fun. Safety programs can be good ways to bring people together. Your commitment to your employee's welfare can be a great morale booster. Competitions, prizes, rallies are all ways to keep up interest throughout the year.

Safety programs are winners for all parties concerned. Employees benefit from increased concern for their health and welfare, the employer benefits from better chemical management and lower accident costs. And the environment benefits from less pesticides use.

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The Texas Rose Industry

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The Texas rose-plant producing industry had its beginnings in the mid-1800s in the northeast Texas area near Tyler. The first recorded sale of rose plants was in 1879, while the first train carload was shipped in 1917. By the late 1950s, over 20 million plants were being harvested yearly by almost 300 growers. Since that time, rose production has stabilized at around 8 to 10 million plants per year grown by fewer than 50 growers on approximately 800 to 1,000 acres within a 30-mile radius of Tyler. Texas produces 16% to 20% of the U.S. total. Arizona and California also have large centers for rose production.

The rose processing industry began to grow rapidly during the late 1940s and 1950s when growers started using cold storage facilities and plastic bags for packaging. In addition, the process of wrapping rose plant roots in paper and inserting them into plastic wrappers with the label was mechanized in the 1960s. Today, approximately 16 million plants are processed locally for mass market sales across the U.S. This figure includes the local production as well as plants imported from Arizona and California.

Another established segment of the industry that is still growing is the forcing of bare-root field-grown plants in containers. Approximately 2.5 million plants are shipped annually from the Tyler area in leaf or bud and bloom for garden center sales. Also, many of the bare-root plants that are forced in containers in other parts of Texas and the U.S. are shipped from Tyler area rose-processing companies.

The total wholesale value of the rose plant production and processing industries in northeast Texas is currently estimated at approximately $50 million per year. This represents a large part of the estimated $150 million in ornamental plant production found in the northeast Texas area.

As with any commodity, there are advantages and disadvantages to producing roses in northeast Texas. The sandy acid soils, relative abundance of rainfall (45 in. per year), and mild winters combine to give many advantages for field production. In addition, the central location of Tyler and proximity to major transportation corridors have aided the development of the processing industry. On the other hand, summer drought, short episodes of severe winter cold, early and late freezes and any problems with the supply of plants from western growing areas are the disadvantages that affect profitability of all phases of the industry. Because of the cost-intensive nature of and required skills for field production, few new individuals are entering the business. However, the industry still consists of many family-owned businesses. Though fewer in number, members of the younger generation are entering the business.

The two-year production cycle of a rose plant begins with land preparation. The summer and autumn prior to planting, a field is cleared of cover crops and weeds, deeply cultivated and fumigated. In addition, the soil is tested to determine the need for adjusting the pH with limestone and to insure that phosphorous levels are adequate. The field is then bedded in rows 44 in. apart.

Planting of rootstock cuttings begins in late November and December. Eight-inch cuttings of*Rosa multiflora* are cut with a saw from canes taken from plants in a field that has been in production for one year. All the buds except the top two or three are removed to reduce suckering. They are stored in plastic bags until planted and can be held at 35°F for as long as two weeks if necessary. Just prior to planting, the beds are shaped, opened slightly by slicing vertically with a coulter and marked with a rolling cylinder consisting of cross bars spaced on the cylinder at the desired width for spacing. As soon as possible after preparation, the cuttings are planted 6 to 7 in. deep and 6 in. apart. After planting, the beds are sprayed over the top with a preemergent herbicide to reduce the growth of winter annual weeds.

The following late winter and early spring, the sides of the beds are lightly cultivated to aerate and to begin leveling the field. By mid- to late April when the rootstock plants have shoots 6 to 12 in. long, the beds are removed by scraping the soil with bars running 1 to 2 in. on either side of the row. The soil remaining between the plants in the row is then blown out with a blower attachment mounted on a tractor. The field is then level and the shanks of the rapidly growing rootstock plants are exposed.

By May, the rootstock plants are ready for T-budding. A team of two persons performs the operation with one doing the actual budding followed by another who does the tying. The standard T-budding technique is followed using budwood harvested the previous autumn (see below). Budding rubbers are tied with only the bud itself exposed to light and air. After budding, a pre-emergent herbicide is applied to the soil to prevent summer weed growth.

During the summer after budding, the main task is weed control using herbicides, cultivation, and hand weeding. Some of the scions begin to grow at this time, but most growth is made by the rootstock. By autumn the rootstock canes are large enough to harvest for cuttings to begin the next crop. In late Autumn, soil is thrown to the plants by disking to protect the graft union from freezing. This practice also aids in weed control when the field is releveled in late winter.

In late winter, the rootstock tops are removed with a cut made slanting away from and just above the graft union. This is done manually or with pneumatic shears. The tops are mechanically chopped and blown back over the field. A preemergent herbicide is then applied. A balanced fertilizer is applied in two or three applications from April to June. Also, the rapidly growing scions are topped by mowing periodically during April and May to decrease damage from wind and to increase branching from the graft union.

The main task during the second growing season is weed control, as described above, and disease control. Black spot is the most devastating disease. Roses must be sprayed with a fungicide weekly from March until harvest.

As the crop matures in the second autumn, budwood is harvested for use the following spring. Mature wood about pencil size from the upper canopy is cut, wrapped in wet newspaper, wrapped in plastic, boxed, and placed into cold storage at 30±1°F.

Digging usually begins in November when starch tests indicate a high level of starch in the dormant canes. This test is also used to aid timing for budwood collection. Prior to digging, the plants are mowed to about 18 in. A shaker digger with a U-shaped blade is then used to remove the plants from the ground. Crews manually bundle the plants by groups of 10 and load them onto a truck. After the

load is tarped, the plants are taken to a processing facility where they are unloaded, graded, dipped into a fungicide, and placed into cold storage by cultivar and grade.

As needed, plants are removed from cold storage and either shipped bare-root for potting and forcing or packaged. For packaging, plants are either placed in a wrapped-root plastic sleeve or are planted in a degradable pot and slipped into a plastic wrapper. For both packaging methods, canes are dipped in a hot wax developed for roses to prevent moisture loss. Marketing begins in January in the southern United States and continues until May in the northern United States.

Planting a Positive Future—An Overview of Three National Tree Planting Programs

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INTRODUCTION

Of all the many national tree planting programs, the American Association of Nurserymen (AAN) believes that three have great potential to benefit nurserymen, plant propagators, researchers, and horticulturists. I'll briefly describe what each of these programs is trying to accomplish and how each one works. I'll also tell you whom to contact for more information and give you an idea of what these programs can mean to you.

SMALL BUSINESS ADMINISTRATION (SBA) PROGRAM

The U.S. Small Business Administration (SBA) set up a program in 1991 to increase environmentally-beneficial tree plantings on state or local government lands. It was also designed to benefit small businesses that provide, install, and maintain plant material.

The SBA program provides federal funds for tree planting. These dollars are matched by state or local government funds or in-kind contributions. A total of $16 million in SBA funds is available for fiscal year 1993 (which began October 1st). These funds are available to states on a population-based formula.

Local governments can apply to a governor-designated state agency for a grant though this program. Usually, the state forester or urban forester is the SBA tree-planting program coordinator. To receive a grant, local governments must provide a minimum of 25% in matching funds or in-kind contributions. Some towns have used maintenance services as in-kind contributions. The SBA grants can be used to purchase, plant, and maintain trees in the community.

In this program trees must be planted by small businesses and may come from either private nursery growers or state foresters. The SBA's definition of small business is one with less than 100 employees.

This program is relatively simple and has generated some substantial dollars for new plantings. The federal government's fiscal year is from October 1 to September 30. In fiscal 1991, the program's first year, $35.5 million was generated for tree planting. Fourteen and a half million came from the federal government. The remaining $21 million came from matching local contributions. These dollars helped plant over 4.5 million trees in more than 1,000 projects.

In fiscal year 1991, the program's second year, $15.7 million was contributed by SBA. Local government contributed $20.6 million resulting in a total of $36.3 million in new tree-planting activity. The state of Texas, for example, generated tree-planting funds of nearly $2.5 million. Florida had similar success, generating funds of over $2 million. Georgia generated over $900,000 in tree-planting funds. And the list goes on.

Contact your state forester for a grant application, along with program rules and deadlines. Usually that person is the program coordinator. Once the information

is in hand, work with your local government to apply for grants.

One AAN member worked with local government and obtained a $15,000 SBA grant for a street-tree program. He offered this advice to nurserymen and women who hope to copy his success:

1) Build a rapport with city officials,
2) Get information from your state program coordinator,
3) Prepare to do a selling job to local government,
4) Don't forget that you can work with more than one town on grant proposals.

The SBA tree-planting program is having a positive, measurable impact during challenging economic times. Not to be outdone, the private sector has also introduced some promising programs. TREEPOWER is one of these.

TREEPOWER

In 1990, the American Public Power Association (APPA) introduced an ambitious plan to plant 16 million trees. This means one tree for each U.S. public power customer. APPA is the trade association representing publicly-owned utilities.

Utilities are interested in tree planting for two reasons. First, state regulators are increasingly urging, or mandating, them to implement programs to help reduce consumption. They call it demand-side management. Fortunately, there is a growing body of science that is making the case for tree planting as a cost-effective way to conserve energy. The utility industry is beginning to recognize this.

Tree planting also builds community relations. Utilities deal with some pretty tough issues, like rate increases, the controversy over global warming, and possible health effects of electromagnetic forces (EMFs). Positive recognition isn't always easy to come by. Sponsoring a tree planting is a terrific way to show good corporate citizenship.

The APPA actively encourages its member utilities to develop TREEPOWER programs in their service areas. They offer plenty of how-to help in designing a program and in generating publicity. AAN offers its member as a resource to utilities for technical information, plant material, and maintenance services.

We at AAN believe this program has tremendous potential. Already hundreds of thousands of trees have been planted across the United States, and an additional 1.5 million trees have been pledged to be planted. Just a few examples: The Omaha, Nebraska, public power district has committed to planting 50,000 trees each year. In Utah, the Murray City Power Department is planting 350 trees a year. The city of Manassas, Virginia, plans to plant about 1,500 trees a year. And the New York Power Authority has allocated $50,000 a year for 5 years for plantings. These are significant planting programs with real dollars behind them. AAN expects TREEPOWER to grow as the tangible benefits of trees become better understood and valued.

COOL COMMUNITIES

During the past three years, we've seen a tremendous amount of interest in urban forestry. We see it in the rise of volunteer tree planting groups, in the emergence of private sector programs like TREEPOWER, and in the increasing federal expenditures on urban forestry. In fact, current congressional appropriations of nearly $25 million for urban and community forestry represent a ten-fold increase over the last 3 years.

We've also seen the birth of a refreshing, new federal strategy to encourage environmental improvement and energy conservation. Instead of the traditional command and control regulatory approach, the Department of Energy and the EPA are experimenting with a new strategy that is more proactive and positive. Cool Communities is an example of this new thinking.

The program is a joint effort of American Forests (formerly the American Forestry Association), the Department of Energy, EPA, AAN, and the utility industry.

Cool Communities is a 5-year experiment. Its main goal is to gather scientific data on the cooling and energy-saving benefits of trees and surface lightening. Surface lightening is a fancy term for painting roofs, streets, and sidewalks white. Another important goal is to educate the public about the value of trees in energy conservation.

Why plant trees? Because our cities are too hot. In fact, it's been shown that they're up to 10 degrees hotter than the countryside. Scientists call this the "urban heat-island" effect. Studies shows that this added warmth costs us up to $1 million an hour in air conditioning. It also helps create unhealthy smog levels. Research also shows that planting the right trees in the right places could cut energy use by 10 to 50 percent.

Seven cities were chosen as models for the Cool Communities experiment: Tucson, Arizona; Frederick, Maryland; Tulsa, Oklahoma; Austin, Texas; Dade County, Florida; Springfield, Illinois; and Sacramento, California. As we speak, Cool Communities staff are organizing project teams in these cities. Participants will include local nurserymen and women, city officials, utility executives, and scientists. Job one is to conduct tree inventories and gather data on energy use and citizen awareness. The next step will be to begin public information campaigns.

Progress reports will be issued every two years and a final report will be published at the end of the fifth year. What does the Cool Communities program mean to you? We believe it will have a tremendous impact on how trees are used in energy saving programs. All of us know that trees are more than an aesthetic enhancement. We know that trees are a practical, cost-effective investment to save energy. And we know that trees are the only part of the urban infrastructure that appreciates. Roads, sidewalks, and bridges depreciate after construction.

Cool Communities will carefully and systematically measure the energy-saving benefits of trees. This data will enable us to bring a critical dollars and cents reality to our marketing because when we talk about the benefits of trees in economic terms, we are speaking the language of the developers, builders, governments, and homeowners.

THE FUTURE OF TREE PLANTING PROGRAMS

AAN believes that the long-term outlook for more environmental tree planting is very positive. The public is concerned about the quality of our air and water. Their concern weighs on the minds of public policy makers, who are looking for new solutions. New approaches, like Cool Communities, represent an exciting, positive response to the challenge of energy conservation and pollution prevention. All of *these trends mean opportunity—and challenges—for everyone involved with the* nursery industry.

What will your role be in the future of tree-planting programs? As propagators and researchers, you will play a critical role in the development of our future tree

supply. We believe that the marketplace will gradually become better educated about tree selection, planting, and maintenance. As this happens, the demand for high-quality, disease-resistant, drought-tolerant plant material will increase. It won't be easier to grow and sell trees, to be sure. But the grower who stays in touch with and meets the market's needs will be best positioned to reap the rewards.

It is AAN's commitment to continue to be a strong advocate for more trees in our cities and communities. And we will always promote the concept of the right tree in the right place. We will continue to seek out partnerships with groups that promote responsible tree planting, and continue to work closely with nurserymen and women to understand your needs and challenges.

I had a high school football coach who always said that "there's no such thing as luck." "Luck," he said, "is when opportunity meets preparation." I can't think of a better way to sum up the challenge—and opportunity—we all face today as we plant a positive future for our industry and for our world.

In Vitro Propagation of Modern Roses

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Modern roses (*Rosa* spp.) comprise the major share of rose propagation for cut-flower sales and landscape use (Wolf, 1983). With a steady to increasing market demand (Federal-State News, 1989), more efficient propagation strategies would be economically advantageous. Modern roses are primarily propagated by T-budding, partly due to difficulties encountered in attempting to root cuttings. T-budding propagation takes approximately 16 months (Davies, 1980; Khosh-Khui,1982). In vitro propagation of modern roses may be a viable alternative for commercial rose production in the future (Queralt, 1991a; Shirvin, 1990). Goals could include, disease elimination and cultivar improvement as well as faster production.

In vitro regeneration of modern roses from explants other than preformed meristematic buds has been difficult. Successful shoot multiplication in vitro has been achieved on a few modern rose cultivars using shoot tips and axillary buds (Bressan, 1982; Douglas, 1989; Hasegawa, 1980). However, in vitro rooting of shoots was a common problem (Alderson, 1988; Bressan, 1982; Douglas, 1989). To make in vitro propagation of modern roses applicable to commercial propagation, reliable rooting methods must be developed.

Two main objectives were outlined that are adaptable for use on a number of cultivars. In order to achieve this we needed to: 1) define a medium or media that will induce rhizogenesis on internodal stem explants of modern roses and, 2) adapt the rooting protocol for shoots derived from axillary buds on six modern rose cultivars.

MATERIALS AND METHODS

Internodal-Stem Explant Preparation. Young vegetative shoots (10 to 15 cm in length) of ' Mister Lincoln' roses were collected from the Disease Research Rose Garden at Mississippi State University. Shoots (minus leaves) were disinfested by immersion in 20% Clorox plus 0.5% sodium dodecyl sulfate (SDS) for 15 min, then rinsed four times with sterile distilled water. Stems were cut into internodal sections, 7 mm long, and split longitudinally. Ten internodal sections were placed cut surface down onto each of 16 different media containing four concentrations each of NAA and TDZ (Table 1). The basal medium was of Murashige and Skoog basal salts (Murashige, 1962); vitamins (per liter: 100 mg myo-inositol, 1.0 mg thiamine-HCl, 0.5 mg nicotinic acid, 0.5 mg pyridoxine-HC1); 30 g/l sucrose; and 8 g/l phytagar (Gibco). The pH was adjusted to 5.8, then steam sterilized. Filter-sterilized plant growth regulators were added to media after steam sterilization. All tissue cultures were placed in growth chambers with a 16-h photoperiod, 4.1 Klux with cool white fluorescent bulbs, and 25/21°C day/night temperatures.

Nodal-Stem Explant Preparation. Nodal stem explants of 'Mister Lincoln' roses were obtained under the conditions stated above, except for the surface disinfestation time (25 min) and explant length (7 to 10 mm). Five explants were

placed per plate. All nodal sections were initially placed onto MS medium containing 0.15 mg/l NAA and 3.0 mg/l BAP (6-benzylaminopurine) to stimulate axillary bud break and shoot multiplication. As shoots reached 10 mm in height (approximately 3 weeks), they were excised from the node and transferred (5 shoots per plate) onto each of the 6 rooting media determined the best from the internodal study (Table 2).

Table 1. Effects of NAA and TDZ on in vitro rhizogenesis of'Mister Lincoln' stem explants[1]

NAA (mg/l)	TDZ (mg/l)	Mean no. roots per plate	Mean no. stem rooted per plate
0.0	0.005	0.0 a[2]	0.0 a
	0.01	0.0 a	0.0 a
	0.02	0.0 a	0.0 a
	0.04	0.0 a	0.0 a
0.2	0.005	2.5 a	1.5 a
	0.01	0.0 a	0.0 a
	0.02	0.5 a	0.5 a
	0.04	0.0 a	0.0 a
0.4	0.005	13.0 d	6.5 d
	0.01	11.0 d	5.5 d
	0.02	4.0 b	2.5 a
	0.04	0.5 a	0.5 a
0.8	0.005	10.0 bc	6.5 d
	0.01	13.5 d	7.0 d
	0.02	10.0 bc	6.0 cd
	0.04	7.0 b	4.0 c
NAA × TDZ		**	**

[1] Ten stem explants per plate with two replications.
[2] Means within column not followed by the common letter differ at $P < 0.05$.
** = interaction significant at $p < 0.001$.

Table 2. Root initiation on 'Mister Lincoln' shoots in vitro: comparison of six media[1]

NAA (mg/l)	TDZ (mg/l)	Mean no. roots per plate	Mean no. shoots rooted per plate
0.4	0.005	11.5 ab[2]	4.0 ab
0.4	0.01	6.5 bc	3.5 b
0.8	0.005	14.5 a	5.0 a
0.8	0.01	13.0 a	4.5 ab
0.8	0.02	6.5 bc	4.0 ab
0.8	0.04	4.5 c	4.5 ab

[1] Five shoots per plate with two replications.
[2] Means within column not followed by the common letter differ at $P < 0.05$.

Three media of the 6 tested induced the best rooting response on 'Mister Lincoln' shoots. Shoots from 5 other cultivars ('Canadian White Star', 'Double Delight', 'Lady X', 'Queen Elizabeth', and 'Tiffany') were placed on the 3 media for determination of overall rooting ability. All cultivars were hybrid teas except 'Queen Elizabeth' (grandiflora).

The experimental design was completely randomized. Responses of tissues were observed at weekly intervals. Data were analyzed using the SAS (SAS, 1991) program in ANOVA or general linear model (GLM).

RESULTS AND DISCUSSION

Rhizogenesis on Internodal-Stem Explants. Approximately 14 to 21 days after initial culture, adventitious rhizogenesis was observed on 'Mister Lincoln' internodal-stem sections in 10 of 16 treatments (Table 1). Greater numbers of roots were obtained on media with reduced TDZ but higher NAA supplements. Rooting percentages greater than 59% were obtained on media containing 0.4/0.01, 0.8/0.005, 0.8/0.01, and 0.8/0.02 mg/l NAA/TDZ. The highest numbers of roots per plate (13.0 and 13.5) occurred on 2 media, NAA/TDZ at 0.4/0.005 and 0.8/0.01 mg/l. The highest concentration of TDZ (0.04 mg/l) seemed to suppress the ability of stems to produce roots.

Rhizogenesis on Shoots Derived From Nodal Explants. Differences were observed among 6 media regarding overall rooting ability of 'Mister Lincoln' shoots (Table 2). Greater numbers of roots and higher percentages of shoots that rooted were obtained on 3 media (0.4/0.005, 0.8/0.005, and 0.8/0.01 mg/l NAA/TDZ). Results were consistent with those obtained on internodal-stem explants. As with internodal sections on the media, the least response was obtained on media containing 0.8 mg/l NAA and 0.04 mg/l TDZ.

Table 3. Root initiation on modern roses in vitro: cultivar and media effects[1].

	NAA/TDZ (mg/1)					
	0.4/0.005		0.8/0.005		0.8/0.01	
Cultivar	NR[X]	SR[Y]	NR	SR	NR	SR
Mister Lincoln	10.8 Aa	4.0 Aa	12.5 Aa	4.3 Aa	9.3 Aa	3.8 Aa
Tiffany	3.0 Abc	2.0 Aab	5.5 Ab	4.0 Aab	8.5 Aab	4.0 Aa
Lady X	4.0 Abc	3.0 Aab	2.5 Ab	2.0 Ab	2.5 Abc	2.0 Aab
Double Delight	5.5 Ab	3.5 Aab	5.0 Ab	3.0 Ab	6.0 Aabc	4.0 Aa
Queen Elizabeth	4.0 Abc	4.0 Ab	6.5 Aabc	3.0 Aab	6.5 Aabc	4.0 Aa
CanadianWhite Star	2.0 Ac	1.5 Ab	3.5 Ab	2.5 Aab	1.5 Ac	1.0 Ab

[1] Five shoots per plate with three replications
A, a = Means within rows (NR or SR) and columns, respectively those not followed by a common letter differ at $p < 0.05$.
NR^X = mean number of roots
SR^y = mean number of shoots rooted

Adventitious roots formed on shoots of all 6 cultivars tested (Table 3). Within each rose cultivar, rooting responses on the 3 media were the same. However, the number of roots (NR) and number of shoots rooted (SR) varied markedly from one cultivar to another. 'Mister Lincoln' performed the best overall with a high shoots rooted value and the greatest number of roots produced. 'Tiffany', 'Double Delight', and 'Queen Elizabeth' all displayed an average of 4 (out of 5 total) shoots rooted (80%) on media containing 0.8 mg/l NAA and 0.01 mg/l TDZ (Table 3). 'Canadian White Star' and 'Lady X' responded poorly. This was expected since various explants from these two cultivars customarily respond poorly to all culture conditions tested (data not shown).

SUMMARY

Roots were obtained on all six cultivars tested, which included five hybrid teas and one grandiflora. Based on our results, rose internodal-stem responses to rooting treatments were reliable indicators of shoot responses to those same treatments. Split internodal explants generate twice the number of explants initially as buds, and bud explants take up to 3 weeks to develop before the shoots can be tested. Therefore, obtaining similar treatment responses from the 2 different explants is advantageous.

This is the first report regarding TDZ effects on roses in vitro. TDZ has been used as a substitute for adenine-based cytokinins in many woody plant cultures (Fiola, 1990; Mok, 1987). In bioassays, TDZ behaved like a cytokinin (Mok, 1987) and has been estimated to be 10,000 times more active than other widely-used cytokinins (Pierik, 1987). However, instead of obtaining a shoot-forming response, rooting of rose shoots occurred at lower concentrations of TDZ when NAA was present.

NAA in combination with other cytokinins did not induce root production on stem or leaf explants (data not shown). The ability to root rose shoots and stem explants in vitro, using the same medium should make it possible to maintain stock plants under aseptic conditions without continually culturing explants for shoot development and multiplication. Also through tissue culture, as much as 24 months production time might be saved (Queralt, 1991b). Unresolved, yet very important, questions relate to plantlet viability after transfer to soil, and acceptable growth with own-root systems.

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Container Size During Propagation and Transplant Date Influence Growth of Two *Ilex* Species

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Stem cuttings of *Ilex cornuta* 'Dwarf Burford' and *Ilex* 'Nellie R. Stevens' were direct stuck into four different container sizes and transplanted 10 and 20 weeks later into trade-gallon containers. Shoot growth and root distribution were influenced by container size and time of transplanting. Plants propagated in small container sizes (cell packs and rose pots) when transplanted at 10 weeks had similar root growth outside a quart-container volume compared to plants propagated in large size containers (quarts and trade gallons). Plants propagated in cell packs and rose pots and transplanted into trade gallons 20 weeks after sticking had lower shoot numbers and dry weights compared to plants propagated in quart containers and transplanted at either 10 or 20 weeks. Plants propagated in quart pots were similar in size regardless of transplant date and were the largest plants in the study.

INTRODUCTION

No nursery standards in the southeastern United States specify how long rooted cuttings should be held before transplanting into larger containers. Most information on the effect of transplant time on plant growth is based on work with tree species (Keever et al., 1991). Early transplanting of most tree species resulted in greater shoot and root growth (Harris et al., 1971). Whitcomb et al. (1977) and Appleton and Whitcomb (1983) reported early transplanting dates enhanced shoot growth of several species with the exception of *Pistacia chinensis* and five pine species. Whitcomb (1984) suggested early transplanting is more beneficial for fast-growing species, but has negligible effect on slower-growing coniferous trees. Keever and Cobb (1989) also reported increased growth when cuttings were direct stuck into large containers.

Ilex 'Nellie R. Stevens' and *I. cornuta* 'Dwarf Burford', as with most *Ilex* species, are commonly propagated by direct sticking stem cuttings in small containers. After rooting occurs, plants are transplanted into larger container sizes. The time of transplanting after rooting varies from nursery to nursery. Limited information is available on the influence of container size during propagation and the influence of transplant date with *Ilex* species. The objective of this study was to evaluate the effect of four propagation container sizes and two transplant dates on the growth and development of *Ilex* 'Nellie R. Stevens' and *I. cornuta* 'Dwarf Burford' cuttings.

MATERIALS AND METHODS

Twelve-centimeter, dormant, terminal, single-stem cuttings of 'Nellie R. Stevens' and 'Dwarf Burford' were direct stuck into cell pack (31.4 cm^3), rose pot (220.5 cm^3), quart pot (1047.9 cm^3), and trade-gallon containers (2975.2 cm3) on 4 March 1991.

Cuttings were treated with captan 50WP (1.8 kg/378.5 l) and a 5-sec quick dip of 3,000 ppm KIBA (potassium salt of IBA) and inserted into the propagation medium to a depth of 3 cm.

The medium was a 6 pine bark : 1 sand (v/v) mixture amended with 3.0 kg/m^3 of dolomitic limestone and 0.9 kg/m^3 of Micromax. All container sizes were placed in a glasshouse under intermittent mist (6 sec/4 min). Greenhouse temperatures were maintained at 32/20°C max/min. All cuttings were removed from intermittent mist on 6 May 1991, and fertilized weekly with Peter's 20-10-20 at 250 mg/l. Half of all treatments were transplanted into trade-gallon containers on May 6, and the remaining plants transplanted on 22 July 1991, which was 10 and 20 weeks after sticking.

Plants were harvested on 20 September 1991, 30 weeks after sticking. Data collected included total root dry weight, segmented root dry weight, new shoot dry weight, and shoot number. Root mass was divided into four sectors that corresponded to the four initial container sizes (Fig. 1).

Treatments were organized in a randomized complete block design with four replications of 16 cuttings per experimental unit. Treatment means were separated using least significant difference and are presented as a mean of both species.

RESULTS AND DISCUSSION

Total root dry weight was similar for transplant date or propagation container size (data not shown); however, root distribution was influenced by both. Root dry weights in sector I were greatest for cell-pack and rose-pot liners transplanted 20 weeks after sticking (Fig. 2). These liners were pot bound when transplanted,

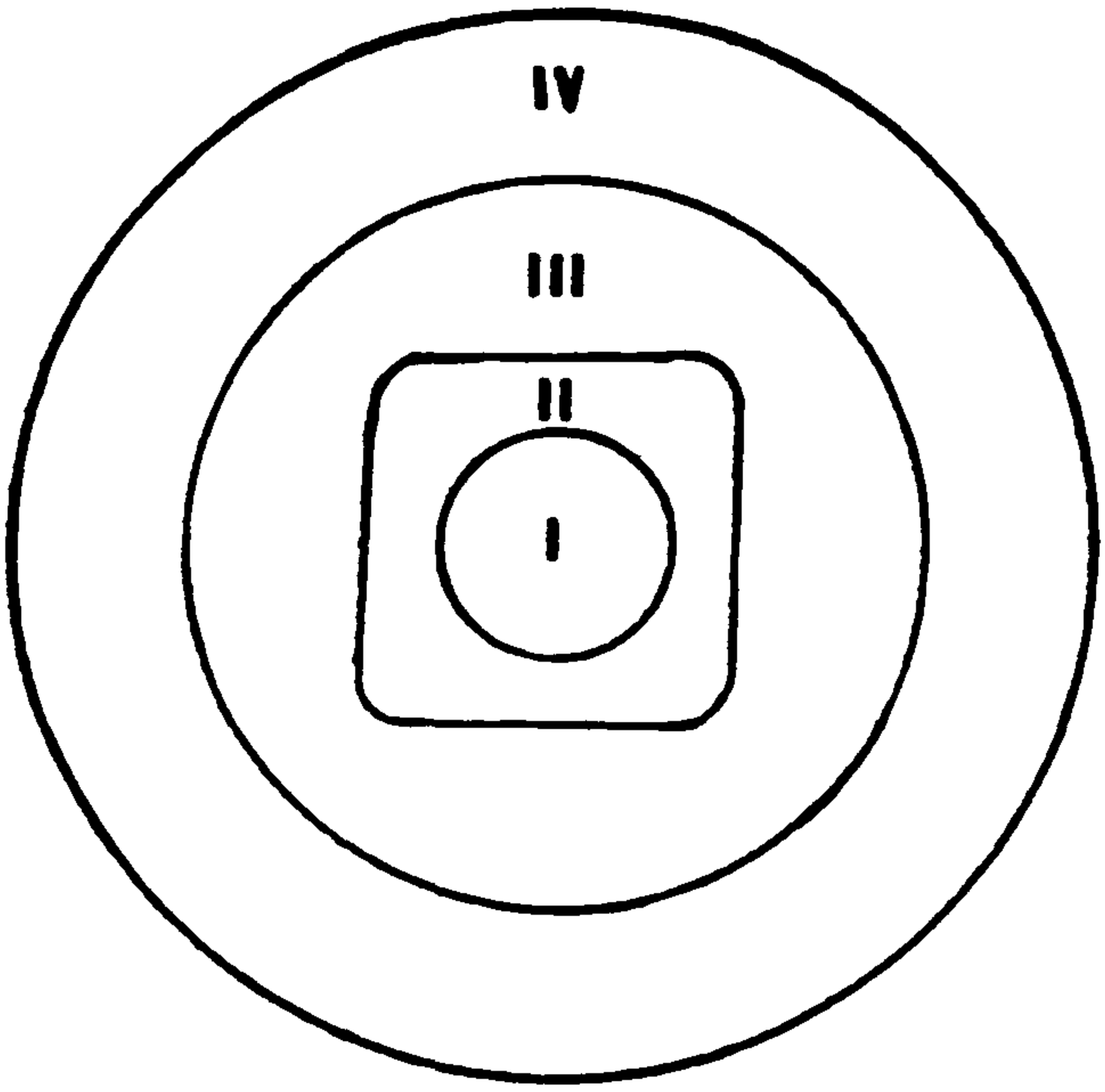

Figure 1. Root sectors used in evaluation of segmented root dry weight. Sector 1(cell pack) had a radius of 2 cm, sector II (rose pot) had a width of 6 cm, sector III (quart pot) had a radius of 6 cm, and sector IV (trade gallon) had a radius of 8.5 cm.

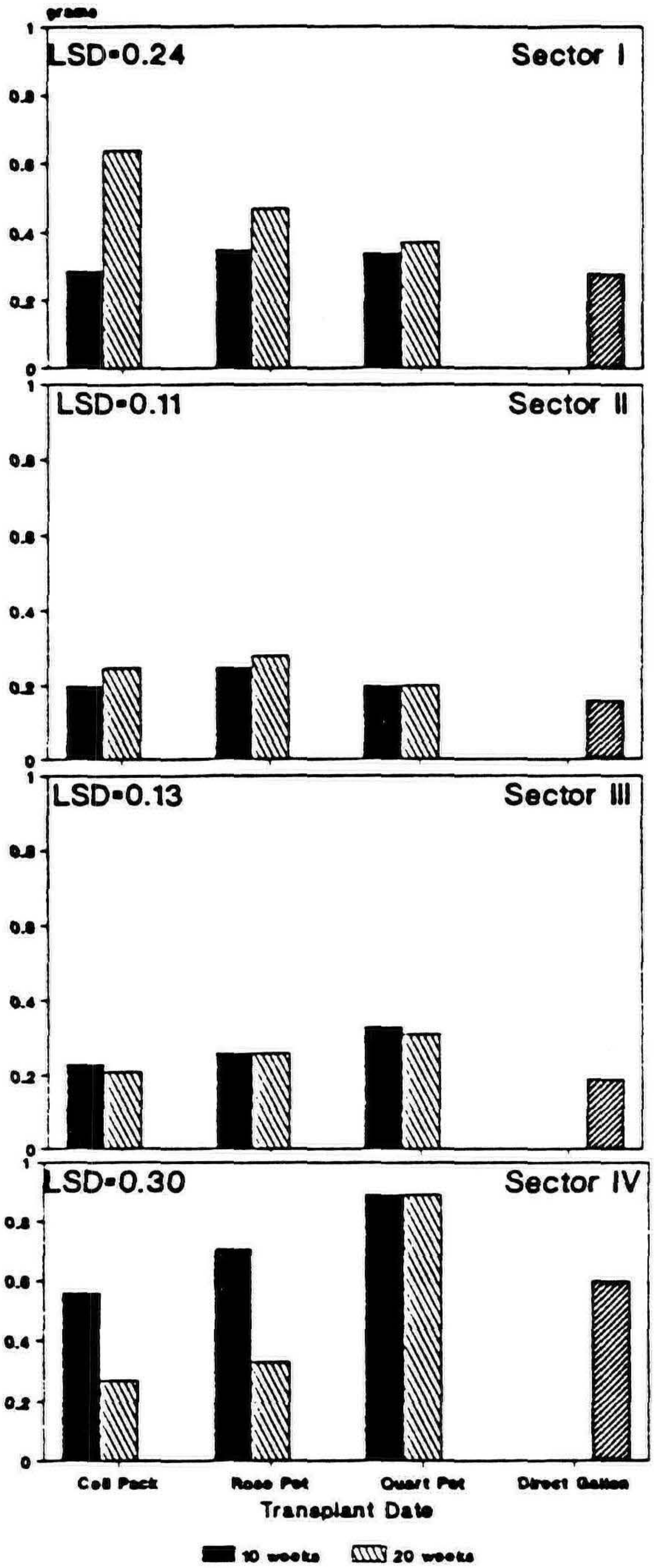

Figure 2. Root dry weight in the 4 root sectors 10 and 20 wk. after transplant.

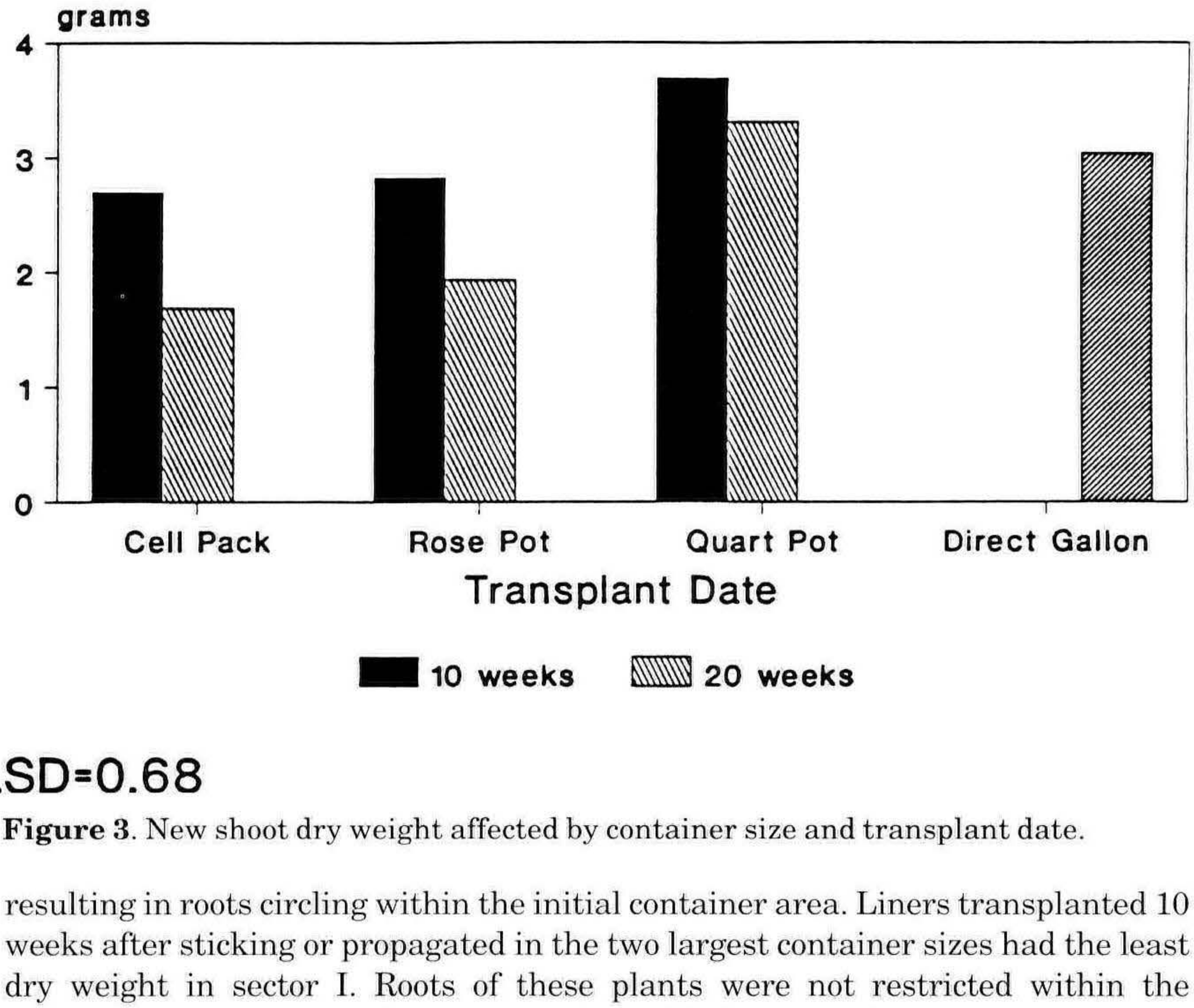

Figure 3. New shoot dry weight affected by container size and transplant date.

resulting in roots circling within the initial container area. Liners transplanted 10 weeks after sticking or propagated in the two largest container sizes had the least dry weight in sector I. Roots of these plants were not restricted within the propagation container and were transplanted before roots began to circle.

In sector II, the rose-pot liners transplanted 20 weeks after sticking had the greatest root dry weight, while the direct-stuck trade-gallon liners had the least (Fig. 2). Again, this probably relates to the condition of the liners at transplanting. The smallest propagation container sizes were pot bound at transplanting and, therefore, had the majority of their root mass confined to a small area.

In sector III, the 10-week quart-pot transplants had the largest root mass (Fig. 2). As with sector II, the direct-stuck trade-gallons containers had the least root dry weight in this sector. Ten-week transplants were not pot bound and had more time to fill the container. Roots of the liners in the trade-gallon containers had already grown past this sector.

In sector IV, the quart-pot transplants had the greatest dry weight regardless of transplant date (Fig. 3). The direct-stuck trade-gallon, the 10-week cell-pack, and the 10-week rose-pot transplants were similar. The 20-week cell-pack and 20-week rose-pot transplants had the least root dry weight in sector IV. These data show that delayed transplanting results in pot-bound liners that respond slowly when transplanted into larger containers.

New shoot dry weight was greatest for plants that were propagated in large container sizes or transplanted at 10 weeks after sticking (Fig. 3). Quart-pot transplants had the greatest shoot dry weight regardless of transplant date, followed by the direct-stuck trade-gallon containers, 10-week rose-pot transplants, 10-week cell-pack transplants, 20-week rose-pot transplants, and the 20-week cell pack transplants. Plants with the lowest root dry weights in the outer container

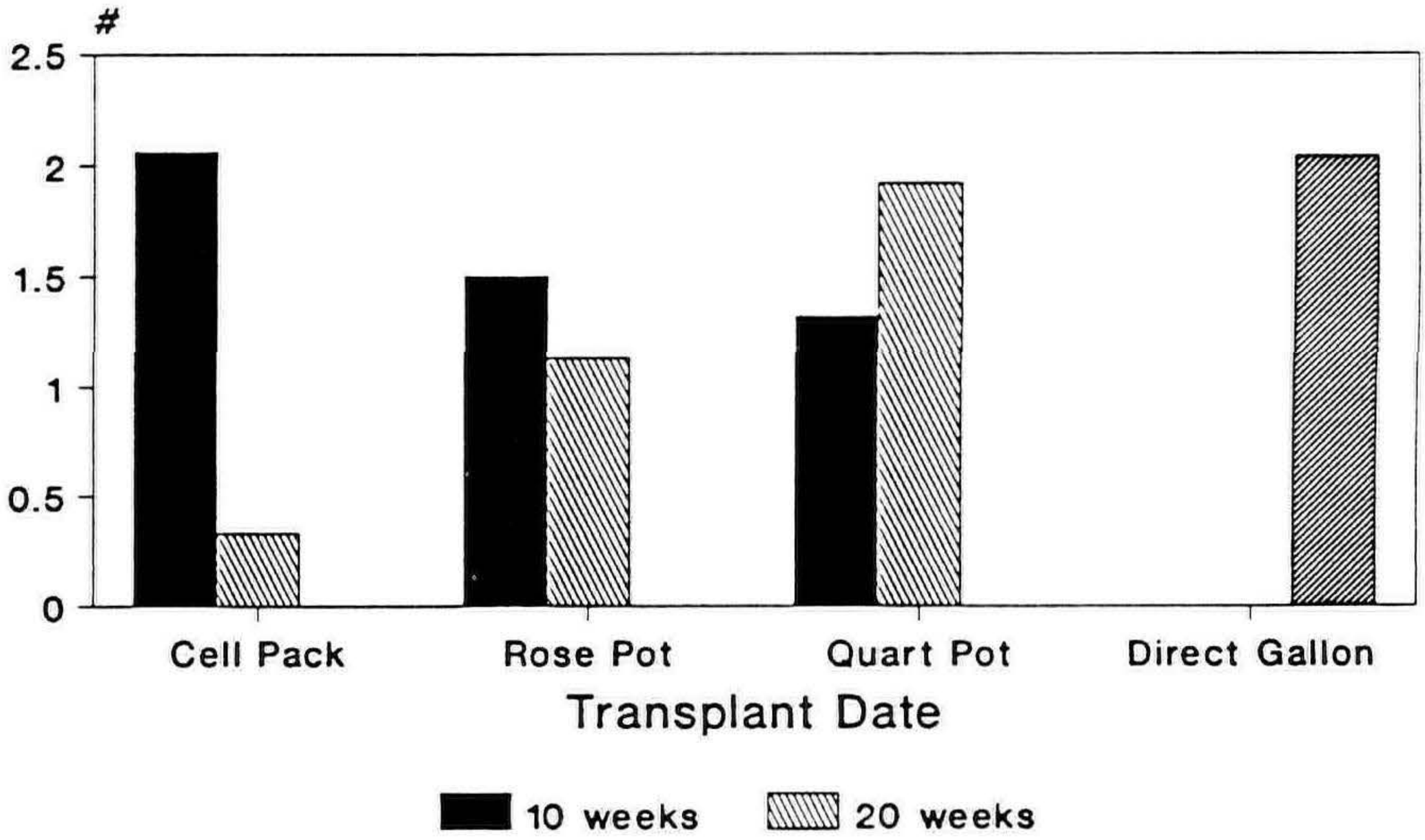

Figure 4. Shoot number affected by container size and transplant date.

sectors generally produced the least new shoot dry weights.

Shoot numbers were greatest for plants propagated in large container sizes or transplanted 10 weeks after sticking (Fig. 5). Liners from direct-stuck trade-gallons, 10-week cell-pack transplants, and 20-week quart-pot transplants had the greatest number of shoots, followed by the 10-week rose-pot and 10-week quart-pot transplants, which were similar, the rose pot transplanted 20 weeks after sticking, and the cell pack transplanted 20 weeks after sticking.

Container size in propagation and transplant date after propagation influenced root distribution of two *Ilex* species, but not total root mass. The smaller the initial container size and the later the transplant date, the more restricted the root system and the longer time required for shoot initiation and elongation to occur. These results are consistent with the findings of Harris et al. (1971), Whitcomb et al. (1977), and Whitcomb and Appleton (1983) who reported early transplanting enhanced shoot and root growth for several species of tree seedlings.

These data demonstrate what can happen in a nursery. If small propagation containers are used, liners must be transplanted soon after rooting to avoid root circling, delayed root regeneration, and slower shoot growth. Growers planning to hold liners for extended periods of time should consider using large pots during propagation.

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In Vitro Culture and Micrografting of White Pine Meristems

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INTRODUCTION

Our long-term research goal is to develop a vegetative propagation method for mature eastern white pine (*Pinus strobus* L.) trees. Unfortunately, rooting from cuttings of white pines, like most other conifers, decreases with increasing plant age. Rejuvenation, that is restoration of rootability to mature tissue, may be possible by tissue culturing or grafting shoot apical meristems. Recently, rejuvenated shoots have been obtained via meristem culture from Sierra redwood, *Sequoiadendron giganteum,* (Monteuuis, 1991) and via meristem micrografting from maritime pine, *Pinus pinaster*, (Dumas et al., 1989). If rejuvenated shoots can be obtained from mature white pines, they will be used as a stock block source of rootable cuttings to clonally propagate superior genotypes. In this paper we describe our efforts to develop methods for tissue culturing and micrografting of white pine meristems.

MERISTEM CULTURE

We have conducted experiments with juvenile (from 4- to 6-week-old seedlings) and mature (from 90-year-old trees) meristems in tissue culture. For dissection, we remove the apical dome and one to several closely appressed leaf primordia, but no primordia which have undergone significant enlargement. Factors investigated include medium mineral salt concentration, growth hormones in the medium, type of sugar in the medium, type of gelling agent in the medium, and addition of complex organic additives, such as coconut water, to the medium. In these experiments survival was generally poor. In a few cases, juvenile meristems grew into shoots and rooted to form plantlets. Survival of mature meristems was even more limited, and made it difficult to reliably assess treatment effects. We then undertook a study to test if inserting a cellulose acetate filter (Romberger, 1970) between the meristem and the medium would improve survival. Use of these filters dramatically improved survival of both juvenile and mature meristems. Shoots developed normally from juvenile meristems, but new leaf production has been

quite limited from mature meristems dissected from branches collected in the spring prior to bud flush. We are currently conducting an experiment to determine if mature meristems from flushing buds initiate new leaves more readily, since spring is the season in which meristems produce leaves for the following year's growth (Owston, 1969). Preliminary results indicate a beneficial effect of bud-forcing on meristem growth and development.

MERISTEM MICROGRAFTING

We have attempted micrografts of meristems onto three stock types: (1) epicotyls of 12-week-old seedlings grown in vitro, (2) epicotyls of 10- to 12-week-old seedlings grown in a greenhouse, and (3) dissected zygotic embryos in vitro. With the in vitro-grown seedlings, no meristem survival was observed and extensive browning and drying of the wounded area of the stock occurred. The greenhouse-grown seedling stock allowed for transitory survival of meristems and less, but still problematical, browning of the wound area. The zygotic embryos appear to be the most promising stock type. We have conducted an experiment to determine the best location of the graft site for juvenile and mature meristems. For both meristem types, grafting onto the embryo hypocotyl at a point midway between the radical and the base of the cotyledons was superior to grafting the meristem just below the base of the cotyledons. To date, we have obtained mature meristems which have survived and exhibited limited growth up to 12 weeks after grafting, and juvenile meristems which are actively growing 14 weeks after grafting. We are currently examining some of these grafts histologically to determine if a graft union has been established. Another experiment currently underway will refine the best site on the embryo for performing the graft, and determine the optimal time to remove the top of the stock plant to permit scion growth.

FUTURE RESEARCH

We intend to use the information from these experiments in both meristem culture and micrografting to develop a method for producing shoots from mature trees. We are optimistic that dissecting meristems from forced branches will provide us with explants that have the potential for vigorous growth and development, and that when micrografting techniques are perfected, zygotic embryos or very young seedlings will provide an excellent stock on which to grow those shoots. Future research will focus on testing the rootability and performance of cuttings from meristem-generated shoots, and developing methods for keeping rejuvenated shoots juvenile so that many rooted cuttings can be produced from each meristem-derived shoot.

ACKNOWLEDGEMENTS

This research has been conducted with financial support from the University of Minnesota Landscape Arboretum, the U.S. Forest Service North Central Station, the International Plant Propagator's Society, and the Horticultural Research Institute. We thank Jennifer Feist, Joan Schneider, and Michelle Steiner for excellent technical assistance, and Kathryn Louis for aiding in the development of meristem dissection techniques. All plant material was generously provided by the U.S. Forest Service Oconto River Seed Orchard.

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Micropropagation of Select Deciduous Trees and Shrubs

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Microplant Nurseries, Inc. has been producing large numbers of trees and shrubs by micropropagation since early 1980. Our main production items have been ornamental and shade trees and fruit tree rootstocks of apple, pear, plum, cherry, peach/almond, and walnut. We are perhaps most well known for our high quality micropropagated *Acer rubrum* cultivars as well as birch, flowering cherry, flowering crabapple, amelanchier, elms, and linden. We carry over 35 lilac cultivars. Microplant also works with individual growers on a proprietary basis growing a whole range of plant material such as bulb crops, small fruits, (grapes, blueberries) and specialty shrubs and perennials.

Our nursery primarily sells product directly from the laboratory either as in vitro rooted plantlets or as microcuttings without roots. Our customers acclimatize the material for themselves. Since we don't handle this step, we have, by necessity, been forced to create a very hardy, relatively large plantlet as our finished product. Our plants must be able to withstand the abuse and neglect of experts and novices alike in a whole host of greenhouse situations. In many cases this means that we use lower levels of growth regulators and accept lower multiplication rates in the process. While it is a bit more expensive in the laboratory, larger plantlets give growers the added advantage of being able to "finish off" their greenhouse growing much quicker, so they can process more plant material in the same amount of space.

As with any propagation system, timing is everything (Driver and Suttle, 1987). While the laboratory can produce material on a year around basis, our customers dictate when they want the product and we schedule our production accordingly. This means that we ship material primarily between the warm weather months of February and August, the peak time being March through May.

Cold storage (in the dark, 2 to 4°C) is an integral part of our micropropagation system. Culture stock (i.e., ripe multiplying cultures) are stored during the off season or in periods of low demand. We've held cultures as long as three years successfully without transferring, although frequent monitoring and annual subculturing is now a regular part of our long term culture maintenance program. Storage of in vitro rooted plantlets—our finished product—provides us with great flexibility. We can prepare plants well ahead of time during the quiet winter months and pull them for shipping in the spring at our customers convenience. We have found that *Malus* and *Pyrus* grow much more rapidly and uniformly in the greenhouse if given at least 1,000 hours of pre-chilling. This chilling requirement is much more of a necessity when planting out occurs during the short-day early spring months.

We have found that some crops, notably *Acer* and *Prunus* do not tolerate cold storage for more than a few weeks. We now cold test plants on a crop-by-crop basis to avoid any catastrophes. When preparing plants for shipping—after rinsing the

agar off of rooted plants or making fresh microcuttings—our plants are immediately refrigerated and remain so all through transit. Once plants are "plucked", we ship immediately and recommend our customers plant out within a day or two – keeping the plants refrigerated until they are ready to plant.

Some very exciting research work has been done on our plants by Dr. Dan Struve (1990) at Ohio State University and Dr. John Day (Day et al. 1988a; Day et al., 1988b; Day, 1992) at the University of Tennessee on extending the growing season using supplemental lights (100 f.c. and long-days) and heat to in effect "jump start" the plants earlier in the season (i.e. January). The results have been phenomenal. Containerized plants of *A. rubrum* cultivars reach caliper growth approaching one-inch after only 8 to 10 months out of culture with stem heights, if left unpruned, reaching 7 to 10 feet! A second year of container growth with suitable top working produces high quality trees approaching 2 in. in caliper. Most commercial growers have not tapped into this rapid growth advantage because supplemental heat and light are expensive, but it has served to open a few eyes to the potential that there may be a better way to do things.

During the past few years Microplant has begun working on the micropropagation of many rare or underutilized specialty plants which need better methods of propagation. Some of the plants we expect to have available soon as small liners are: *Hydrangea quercifolia* 'Snow Queen'(PP4458) and 'Alice'; *Fothergilla* 'Mount Airy', *F. gardenii* 'Jane Platt' and 'Blue Mist'; *Parrotia persica*; *Franklinia alatamaha*; *Corylopsis pauciflora*; *Disanthus cercidifolius*; *Cornus kousa* 'National' and 'Satomi'; *Cercis reniformis* 'Texas White'; *C. chinensis* 'Avondale'; *C. canadensis* 'Forest Pansy' and 'Alba'; and *Styrax japonicum* 'Pink Chimes'.

Over the past 13 years we have seen the nursery industry begin to use micropropagation in an increasing variety of ways. In some cases, the main reason may be to simply increase numbers of a new plant quickly and at some point more traditional methods of propagation such as cuttings, layerbeds, or scaling may take over. In other cases, micropropagation has proven in the field to provide more uniformity, more vigorous growth, more branching, less cullage, better root systems, and less disease than other methods. Some of our customers use it to save money by avoiding costly mother block establishment, to bring in newly released disease resistant or virus free material, to give them more market flexibility, or a more reliable stock source. Sometimes there isn't a single clear overriding advantage at all, it just seems easier. Regardless of the reason, we find it a very rewarding and exciting part of the nursery industry to be involved in. We look forward to the next 13 years.

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Micropropagation of Eastern Redbud (*Cercis canadensis* L.)

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INTRODUCTION

Eastern redbud (*Cercis canadensis*) is an important nursery crop native to eastern North America. It is a deciduous small tree in the legume family. Eastern redbud is a variable species with cultivars selected for lavender, pink, or white flowers (Raulston, 1990). In addition, cultivars have been selected for purple ('Forest Pansy') and variegated foliage ('Silver Cloud'). The inherent variability in this species (Robertson, 1976) indicates a potential to select additional traits such as disease resistance and drought tolerance to improve marketability. However, production of cultivars of eastern redbud have been limited because they are difficult to propagate from cuttings or grafts (Dirr and Heuser, 1987). Progress in the propagation of eastern redbud has recently suggested that cutting propagation can be successful for cuttings taken from mature trees during a narrow developmental window during early shoot development (Tipton, 1990) or with cuttings treated with relatively high concentrations of auxin (Dillion and Klingaman, 1992). Tissue culture offers a commercial alternative for the propagation for cultivars of eastern redbud (Bennett, 1987; Burkhart and Meyer, 1990; Yusnita et al., 1990). Unfortunately, commercial tissue culture production of eastern redbud has been limited by the difficulty in rooting microcuttings of this species. The objective of this communication is to detail procedures for the micropropagation of eastern redbud and the successful rooting of five mature clones.

ESTABLISHMENT OF CULTURES

Establishment into culture of actively expanding spring growth has been difficult because of contamination inherent with tissue growing in the outdoors environment. Successful cultures have been established at a high rate by selecting budwood and forcing shoots to expand in the greenhouse or growth chamber. This technique has worked very well and we have been able to utilize budwood sent through the mail for forcing. Budwood was forced in February by placing 10 to 12 stems per 250 ml of a solution containing 1.0% florist's preservative. This solution was changed as necessary. Vigorous shoots were selected when they reached 3 to 4 cm long. Leafless shoots were disinfected by washing in running tap water for 1 h. This was followed by sequentially treating the shoots with 70% ethanol (10 sec), 1,500 ppm benomyl (10 min), 10% Clorox containing 0.1% detergent (15 min), and rinsing explants with three changes of autoclaved, deionized water. Cultures were established on either WPM (Lloyd and McCown, 1980) or DKW (Driver and Kuniyuki, 1984) medium containing 0.7% agar and 10 µM benzylaminopurine (BAP) in Magenta containers. All cultures have been grown at 24°C (75°F) and a 16 h photoperiod at 30 µmol sec^{-1} m^{-2} provided by fluorescent lamps.

MULTIPLICATION OF MICROSHOOTS

Initially shoots were multiplied on WPM medium containing BAP (Fig. 1). BAP at 10 or 15 µM provided optimum microshoot multiplication from primarily axillary shoots. Thidiazuron was not effective for redbud cultures because of the induction of multiple shoots which were fasciated and failed to elongate. However, Burkhart and Meyer (1990) found suitable shoot multiplication with a combination of Thidiazuron and BAP. Redbud cultures grown on WPM medium soon developed a problem with shoot-tip necrosis. This was adequately alleviated by switching cultures to DKW medium, although additional salt substitutions may be required to completely alleviate this problem. The original work in our lab with redbud micropropagation was performed on a white flowering form (Yusnita et al., 1991). Subsequently, this protocol has also been used successfully to culture both lavender and pink flowering forms, and the cultivars 'Forest Pansy' and 'Silver Cloud'.

ROOT FORMATION IN MICROCUTTINGS

Root formation has been reported to be difficult in redbud microcuttings. Microcuttings did not root without an auxin treatment and failed to respond to quick dip treatments (Yusnita et al., 1990). We were able to achieve high rooting percentages by pulse treating microcuttings with auxin in vitro (Table 1). Previous work indicated that IBA was a more effective auxin than NAA for root induction (Yusnita et al., 1990). Microcuttings rooted at a higher percentage with IBA and the

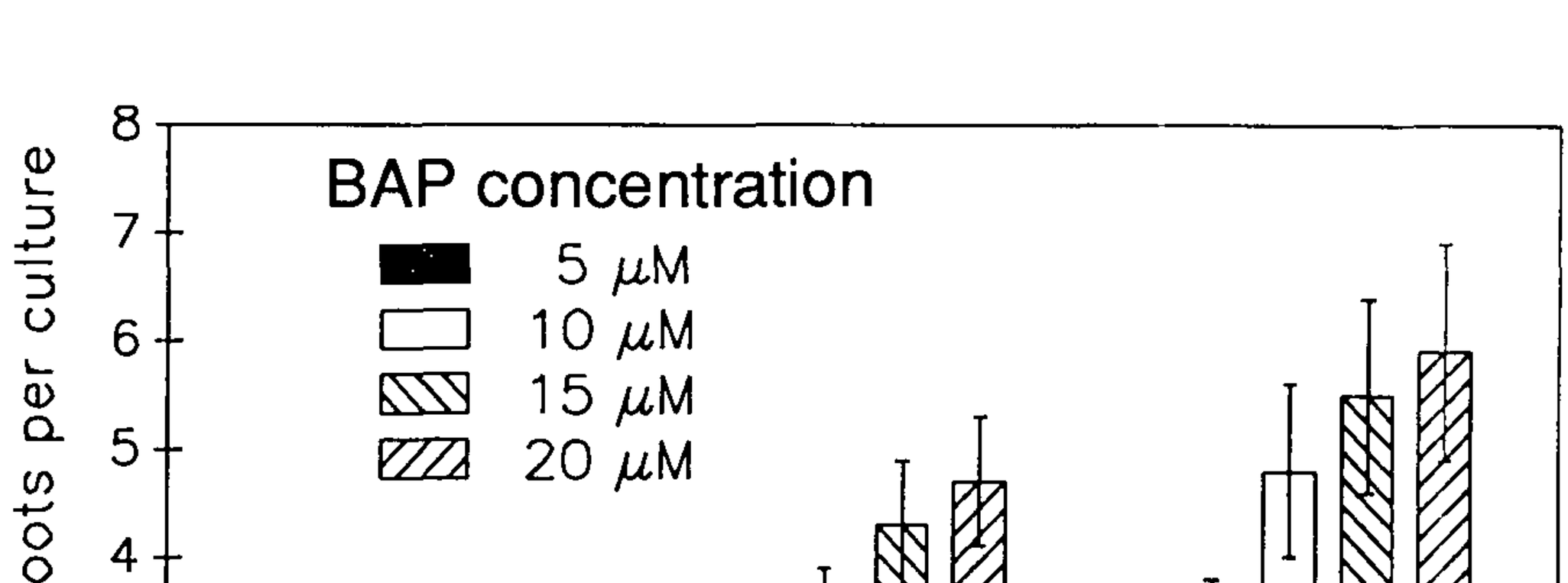

Figure 1. The effect of BAP on shoot formation in explants from white flowering eastern redbud.

subsequent roots formed were more normal with a tendency to branch. The procedure for pulse treating microcuttings consists of sticking 3- to 6- cm microcuttings on half-strength WPM medium salts containing 150 to 300 µM IBA. After 15 days, root primordia have been initiated and microcuttings can be moved to an ex vitro environment. Root development proceeds in a peat and perlite medium in cell packs under high (approx. 100%) relative humidity. Acclimatization can begin after three weeks by gradually reducing the humidity. This procedure has been very successful for rooting several mature clones of eastern redbud (Table 1). Experience with these redbud clones indicates that microcutting size influences the success of this procedure. Larger microcuttings (3 to 6 cm) root and acclimatize at the highest percentages.

Table 1. Root formation in microcuttings from four mature clones of eastern redbud treated in vitro with IBA for 15 days and subsequently rooted ex vitro in a peat and perlite medium.

Treatment IBA [µM]	Rooting (%)	No. roots per cutting
White		
Control	70	1.4
150	93	4.9
300	70	3.8
Lavender		
Control	20	0.3
150	67	3.8
300	53	1.7
Pink		
Control	40	1.0
150	83	6.7
300	83	4.3
'Forest Pansy'		
Control	0	0
300	77	2.2

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Effects of Lighting and CO_2 Enrichment on Acclimatization of Micropropagated Woody Plants

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In order to test the effects of CO_2 enrichment and light intensity on the acclimatization and ex vitro performance of micropropagated woody plants we have designed and constructed an inexpensive CO_2 enrichment/fogging chamber which could be easily adapted for commercial use. CO_2 enrichment during acclimatization has been shown to be beneficial with mountain laurel, lilac, grape, apple, and raspberry, but not with serviceberry, blueberry, or sweet cherry.

INTRODUCTION

The focus of most technical reports on micropropagation of woody plants is on the optimization of the in vitro chemical and physical environment. However, when it comes to managing the transition from tissue culture to the greenhouse or field environment (stage IV or acclimatization), growers are largely left to fend for themselves. This is not surprising since relatively little research has focused on this final but very critical stage of micropropagation despite the fact that it can be critical in terms of success and the overall profitability of micropropagation. A number of crops such as apple and serviceberry proliferate easily in culture, but high losses in the acclimatization phase can render their micropropagation marginally or wholly unprofitable.

The *acclimatization protocol for woody plants in most commercial* micropropagation operations typically involves the transfer of unrooted micro shoot cuttings from the in vitro tissue culture environment, into an ex vitro modified greenhouse environment characterized by high humidity, and low light intensity. Acclimatization systems usually rely on shaded natural lighting supplemented, in some cases, by supplemental lighting for photoperiod extension. Under these conditions, microcuttings are expected to initiate a new adventitious root system as well as new shoot growth.

A problem inherent in acclimatization systems located within a greenhouse facility is that light intensity varies hourly, daily, and seasonally. Consequently, microcuttings experience not only variable lighting, but also temperature, and to some extent relative humidity as well. Furthermore, in tightly closed systems, such as the polystyrene sandwich-type boxes often used for acclimatization, CO_2 concentrations may become limiting during the light period due to photosynthetic utilization of CO_2. Although atmospheric CO_2 concentration has occasionally been experimentally enriched with beneficial effects during in vitro culture (Kozai, et al., 1988) or during stage IV acclimatization (Desjardins, et al., 1990; Lakso, et al., 1986), there is little commercial application of in vitro or ex vitro CO_2 enrichment.

It has been our view that in vitro CO_2 enrichment will be technically difficult to implement and economically difficult to justify because of the difficulty of avoiding contamination in a gas-flow-through system. The acclimatization stage would appear to be a particularly appropriate time to intervene with enrichment CO_2. It could be accomplished at this stage more easily and less expensively compared to the tissue culture (in vitro) environment, or compared to the post-acclimatization stages of greenhouse production where plants occupy a far larger amount of space which would be much more expensive to treat. Our objectives over the last several years have been to develop a practical, economical ex vitro acclimatization system in which CO_2 concentration, light intensity, temperature, and relative humidity can be optimized at an affordable cost to growers.

MATERIALS AND METHODS

We designed and constructed an acclimatization chamber for experimental optimization of carbon dioxide and lighting which allows us to vary CO_2 and lighting in complete 2 × 3 factorial arrangement of treatments, with two levels of CO_2 and three levels of light intensity. The overall six compartment chamber was built within an enclosed basement room with no windows. It was 12 ft long × 6 ft wide. The chamber was subdivided into six compartments in a 2 wide × 3 long arrangement. Each compartment measured 4 ft in length and width and sloped from a height of 22 in. at the back, along the central chamber axis, to 12 in. in front. Walls and floor were constructed from 0.5-in. plywood. Interior walls were lined with waterproof bathroom paneling and the bottom with 1/8-in. thick vinyl flooring. Joints were caulked with silicone. Each chamber had a separate lid, consisting of a wooded sash with clear Flex-O-Pane plastic stretched across it. Lids were hinged in the back and sloped from back to front to facilitate cleaning and to maximize light transmission by encouraging beads of condensation to roll off the inside of the lid.

Three compartments along one long side of the chamber were equipped with a CO_2 enrichment system while the three compartments along the other side were at the ambient CO_2 level of the room (approx. 450 pm). CO_2 level in the enriched side was monitored and controlled with a CO_2 monitor/controller (Horiba Instruments Inc., Irvine, California) set to open a solenoid connected to a tank of compressed CO_2 when the CO_2 level in the chambers dropped below 1,200 pm.

Humidification was provided by four inexpensive, ultrasonic cool-fog humidifiers designed for household use. One humidifier was located at each corner of the overall chamber, and fog was distributed to each of the six individual chambers via ½-in. diameter PVC tubing. Humidifiers were connected to a timer set to a 5-min on/5-min-off schedule, which resulted in 98±2% relative humidity.

Illumination (16 h/day) was from four 8-ft long Cool White florescent tubes running over each high/low CO_2 pair of chambers, perpendicular to the long axis of the chamber. Experimental variation in light intensity was accomplished in early experiments by varying the number of florescent tubes above each pair of chambers, or, in later experiments, four tubes were placed over each pair of compartments and the medium and low light compartments were shaded with one or two layers, respectively, of Saran shade cloth laid directly on top of the lids.

Temperature control within the room (not the compartments themselves) was achieved by means of an air conditioner. To achieve as much uniformity as possible of temperature, CO_2 concentration, and relative humidity between compartments

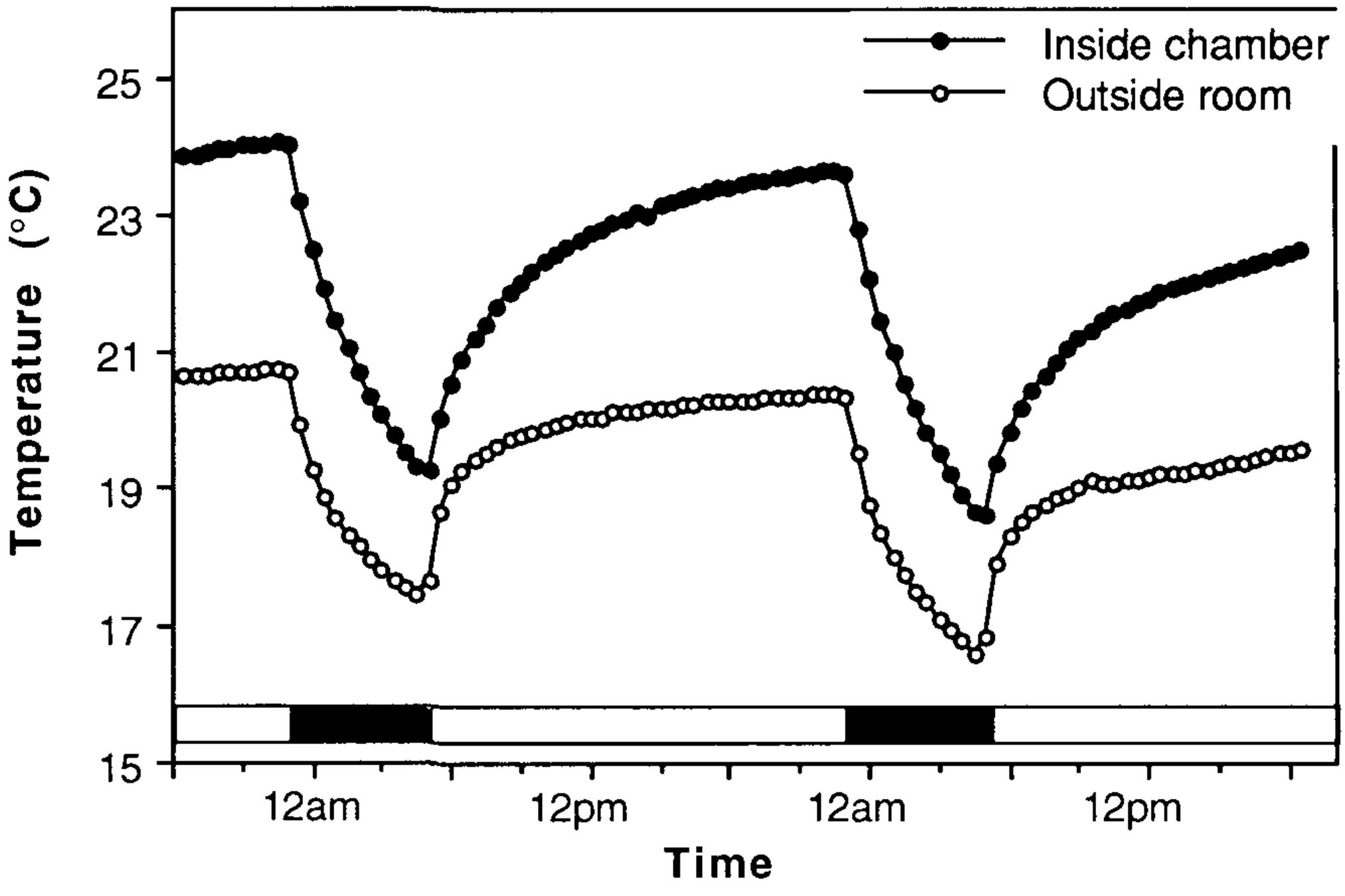

Figure 1. Acclimatization chamber and room temperature variation over time.

(within a CO_2 treatment), the three compartments on either the high or the low CO_2 side of the chamber were interconnected with a pair of ventilation fans in their common interior walls. The two fans in each common wall blew in opposite directions to set up circular air flow with in the three compartments.

Over the past several years, we have conducted the basic 2 × 3 factorial experiment consisting of two CO_2 levels (450±50 and 1,200±200 pm) and three light intensities (specified below for each experiment) with eight species of woody ornamental and fruit crops including mountain laurel (*Kalmia latifolia*), lilac (*Syringa vulgaris*), serviceberry (*Amelanchier canadensis*), grape (*Vitus labruscana*), apple (*Malus sylvestris* var. *domestica)*, sweet cherry (*Prunus avium*), blueberry (*Vaccinium corymbosum*), and red raspberry (*Rubus idaeus*). In all cases, unrooted microcuttings from Stage II shoot cultures were transplanted without rooting hormone into flats containing a suitable rooting medium (peat in the case of mountain laurel, and peat vermiculite for other species). Mountain laurel and grape microcuttings were donated by the commercial tissue culture laboratories (Knight Hollow Nursery, Madison, WI and Congdon and Weller Nursery, North Collins, NY, respectively). The other species were cultured in our own micropropagation laboratory at Cornell using standard shoot proliferation media and protocols.

RESULTS AND DISCUSSION

Figure 1 shows the relationship between photoperiod and temperature in the experimental compartments and in the outer room. Heat generated from the florescent lights increased steadily throughout the light period. Chamber temperature was approximately 3°C higher than room temperature at any given time due

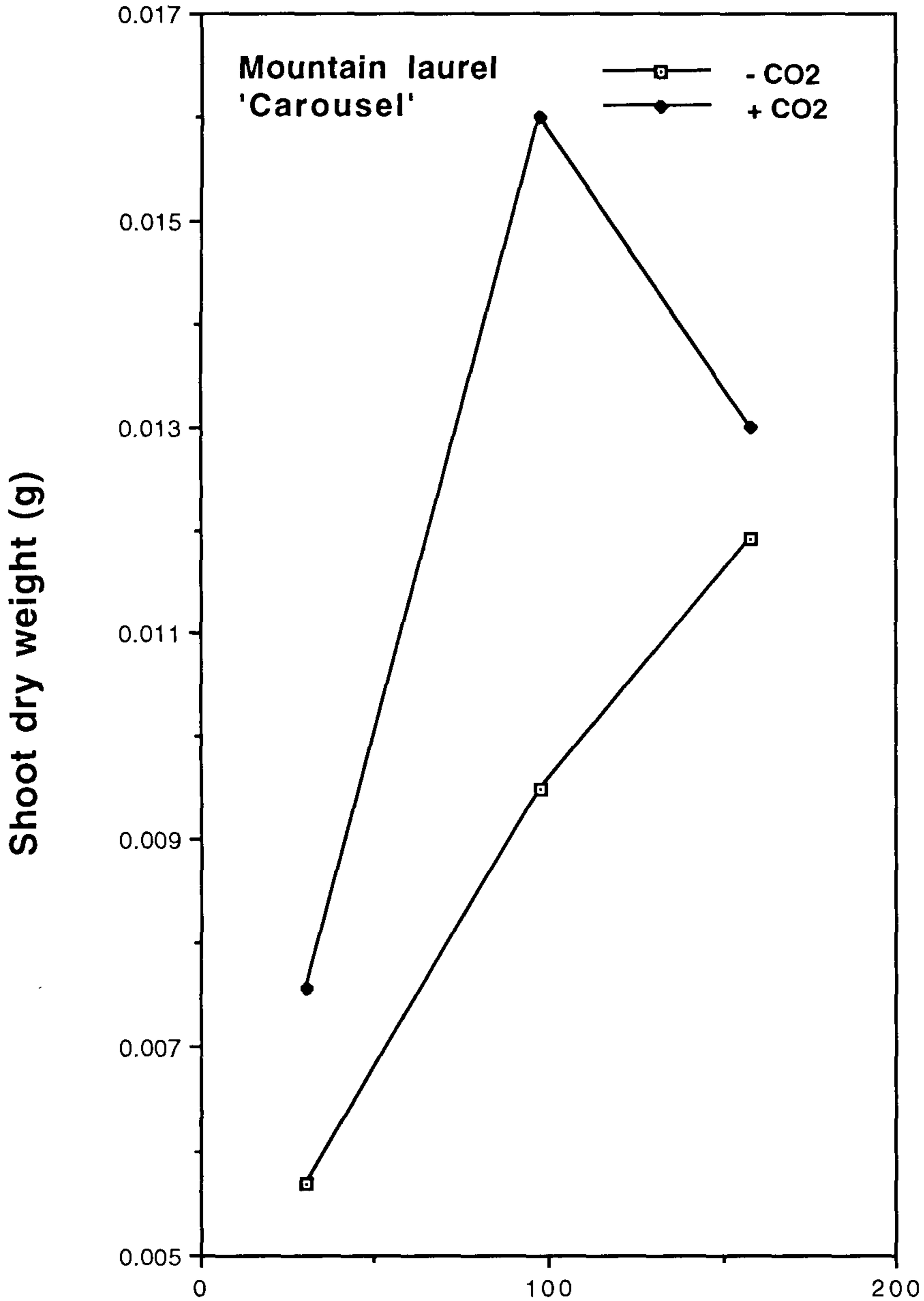

Figure 2. Effect of CO_2 enrichment and light intensity (irradiance) on shoot growth of mountain laurel.

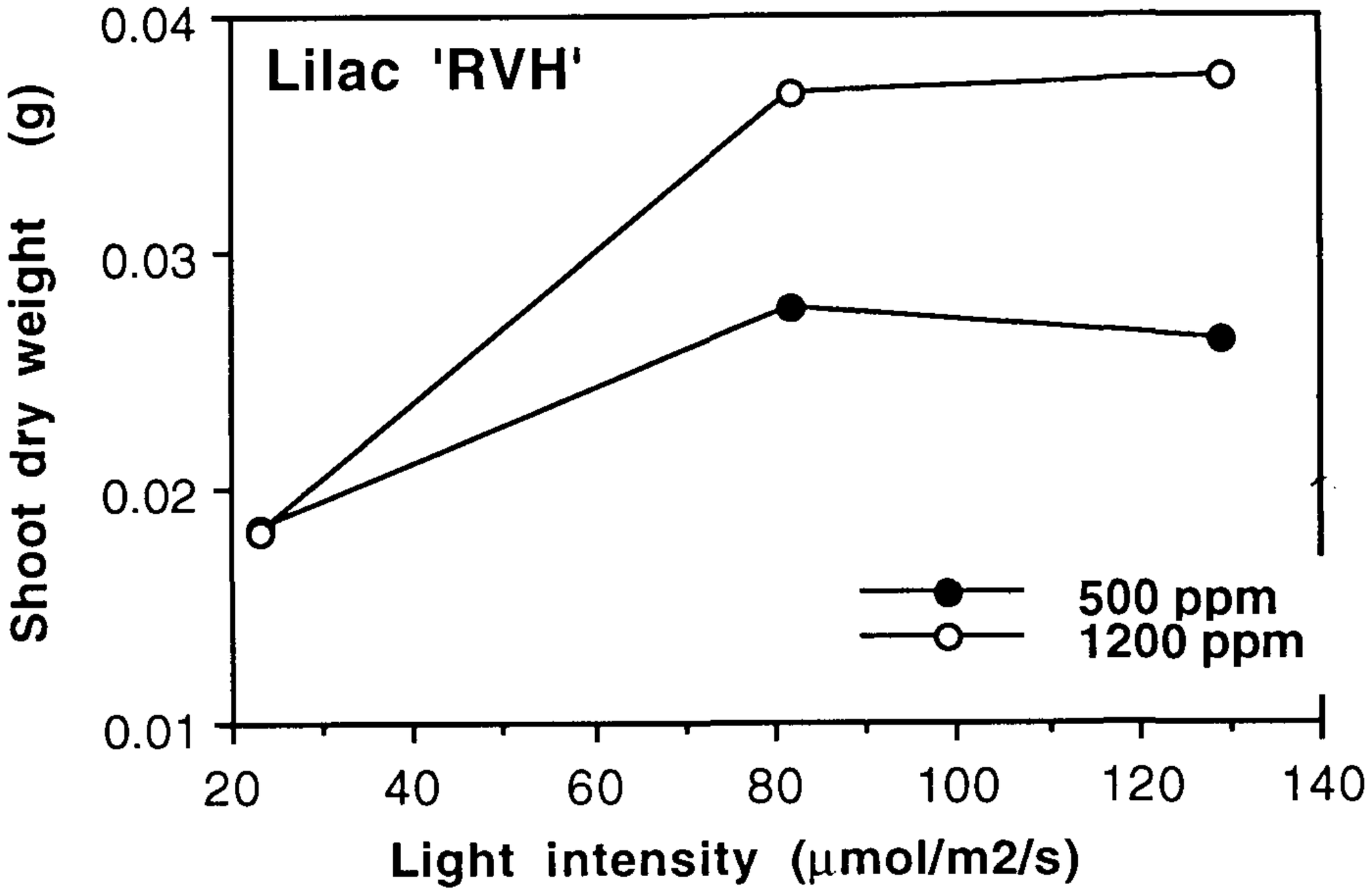

Figure 3. Effect of CO_2 enrichment and light intensity (irradiance) on shoot growth of lilac.

to a "greenhouse" effect. Between compartment temperature variation was no more than 2°C at any given time due to the intercompartment air circulation fans, despite more than 3-fold difference in illumination level from high to low light treatments. There was, however, seasonal variation in room and chamber temperature ranging from a 23°C (winter) to 29°C (summer) (24-hour average).

Our first experiments were conducted with the mountain laurel cultivars Elf and Carousel. Figure 2 shows that shoot dry weight accumulation after 8 weeks in the fogging chamber increased with increasing light intensity and in response to CO_2 enrichment, with the best shoot growth with CO_2 enrichment at the medium light level. Similar results were obtained for the effect of CO_2 enrichment and light intensity on root dry weight except that the CO_2 stimulation was greatest at the high rather than the medium light level.

Figure 3 shows similar results for the lilac cultivar RVH. Both shoot growth and root growth (not shown) were enhanced by CO_2 at the medium and high light but not at the low light level.

Red raspberry, apple, and grape are other species which have responded positively to CO_2 enrichment. Serviceberry, blueberry, and cherry, on the other hand, have not exhibited a positive response to CO_2 enrichment. We believe that the relatively high summer temperatures (29°±2°C) may be a factor in this lack of response to CO_2 enrichment, and we are currently modifying the system to achieve better temperature control. Furthermore, we have noted that all species in the Rosaceae family which we have included in these experiments (serviceberry, apple, and cherry), appear to undergo shoot dormancy or "stall out" during acclimatization. In recent experiments with serviceberry we have been able to

overcome this dormancy to some extent by spraying foliage with 100 ppm gibberellic acid (GA_3) at the time when microcuttings are beginning to root in the acclimatization fog boxes (about 3 weeks after sticking).

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A Survey of Plant Tissue Culture Laboratories in North America

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In 1987, it was reported that there were over 250 commercial plant tissue culture laboratories in the United States (Jones, 1987). However, there has been no comprehensive list of plant tissue culture laboratories published in the United States.

The U.S.D.A. is currently trying to tabulate an accurate estimate of the value of the U.S. horticulture industry. As the micropropagation industry is a major part of U.S. horticulture, it is valuable to know the economic impact from the plants produced in vitro. Before economic information can be gathered, the size of the plant tissue culture industry needs to be known. In order to achieve this goal, we started to tabulate a list of laboratories in the United States, Canada, and Mexico. This compilation will be published as "The Directory of Plant Tissue Culture Laboratories in North America" (Bridgen, 1993). The objective of the Directory was to collate a directory of private and public plant tissue culture laboratories in North America which are involved in commercial production, research, and teaching. Collectively, there is a vast pool of information and skills available in plant tissue culture.

The knowledge and skills required to expand this unique industry requires communication and the directory is a good communication source. The information collated in the Directory will be used to further the support for and the growth of plant tissue culture.

In order to inform laboratory owners and managers of the directory and to invite them to participate in the survey, a questionnaire was place in professional and

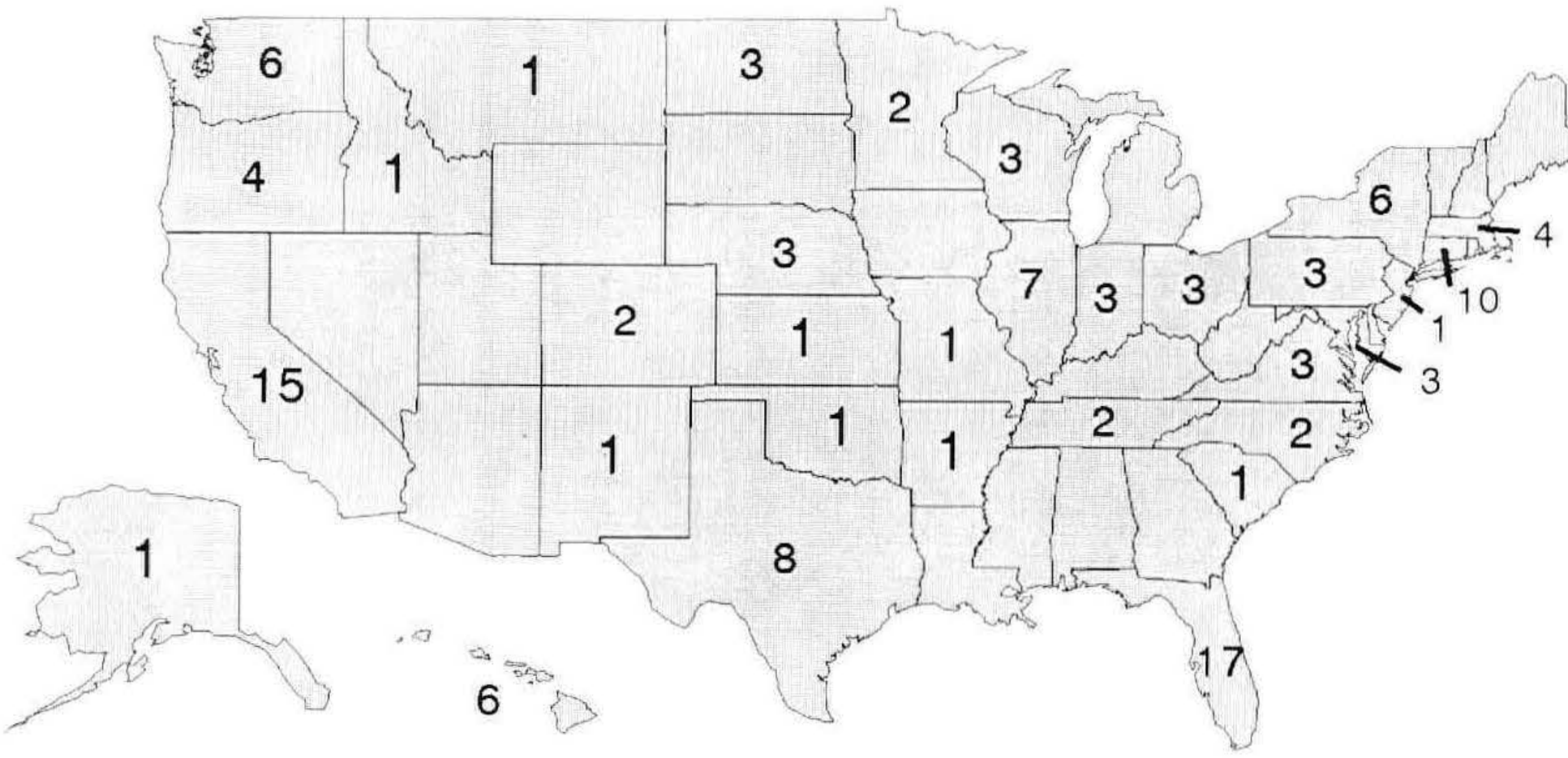

Figure 1. Plant tissue culture laboratories in the United States.

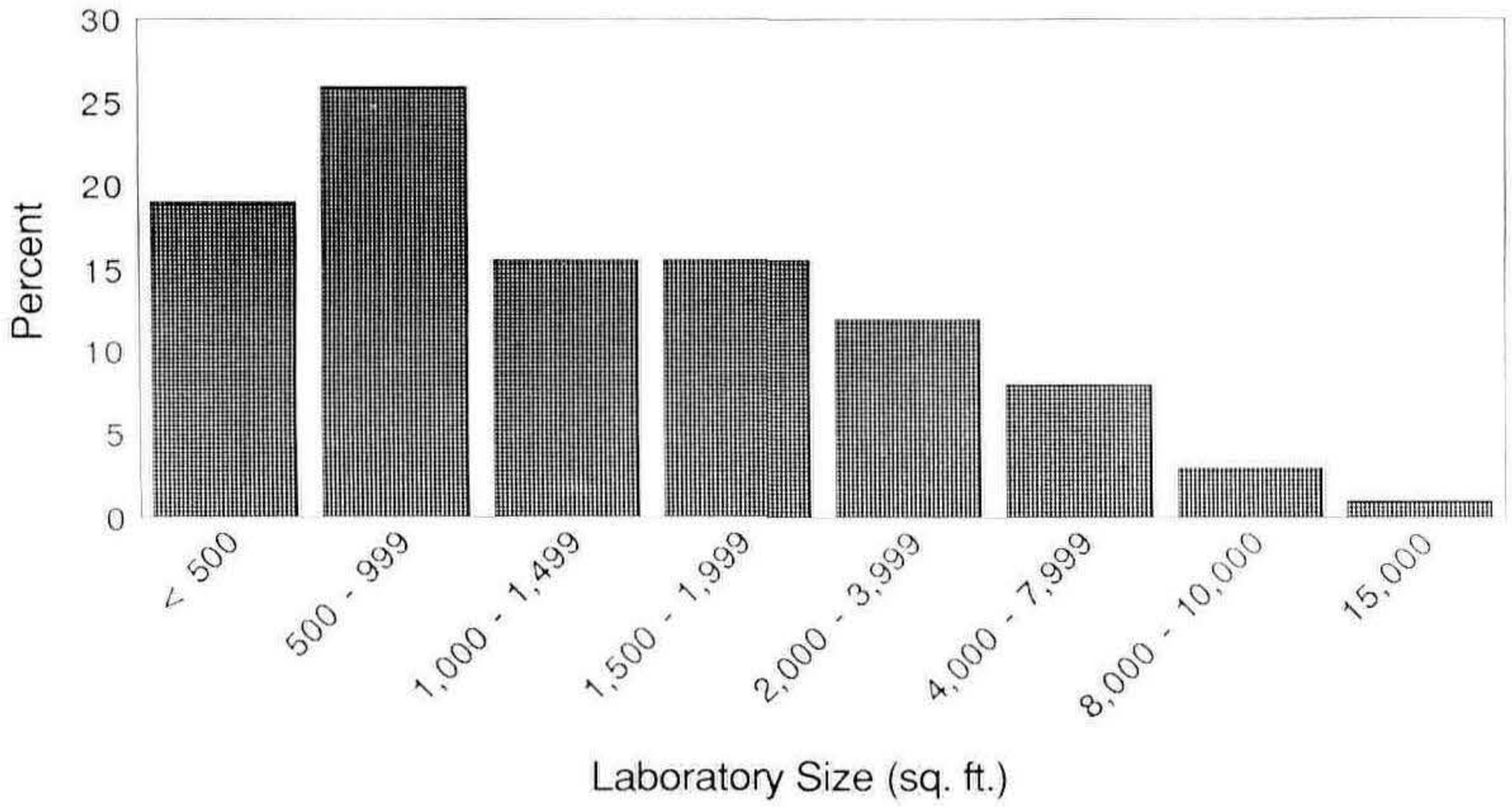

Figure 2. Size distributions of plant tissue culture laboratories in the United States.

industry magazines and newsletters of the horticulture and tissue culture industries. There was no charge to be placed in the directory and responses were completely voluntary. The questionnaire requested the name, address, telephone number, and FAX number of the laboratory and the name of the director or owner. Laboratories were categorized as either private or public; the latter was further subdivided into university or government. Private laboratories could be classified as research and development (R&D), commercial production, or hobby; public laboratories were either research or teaching. An attempt to determine laboratory size was made by asking for the approximate square feet, number of plants produced per year, and number of full-time and part-time employees. Twelve laboratory interests and specialties were listed. Those answering the survey were to indicate the interests or specialties that applied to their laboratory by marking

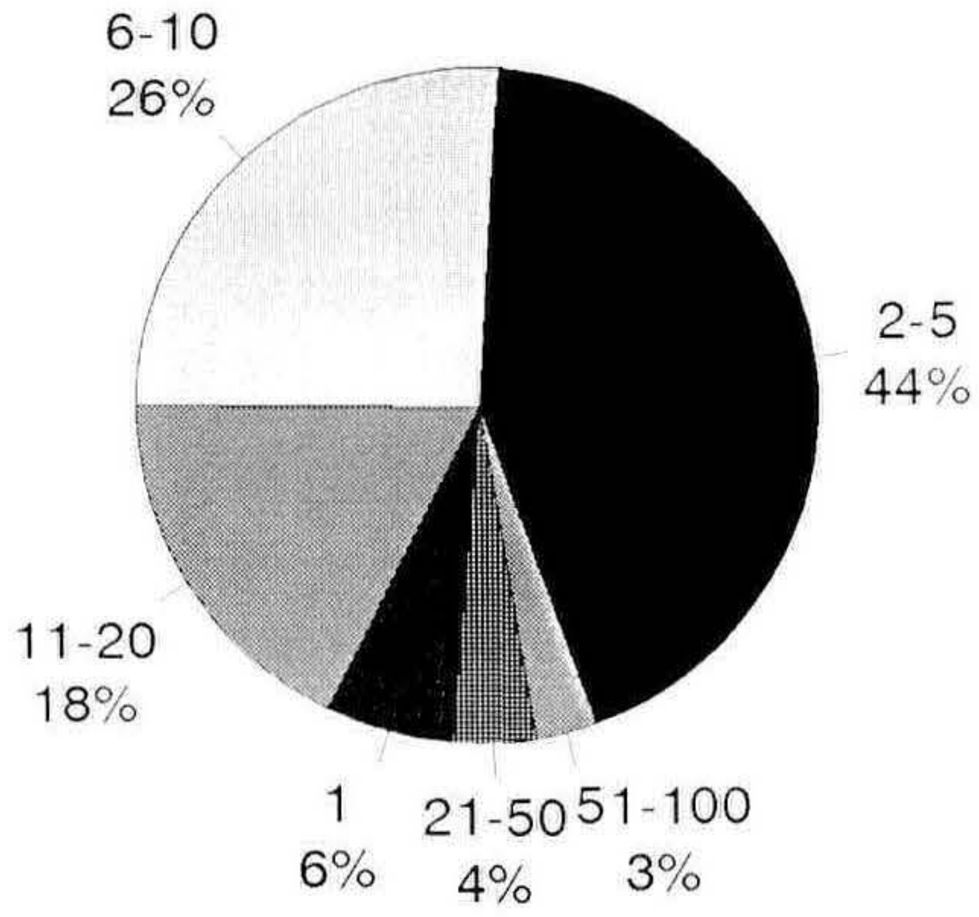

Figure 3. Frequency distributions of the total number of employees working in U.S. plant tissue culture laboratories.

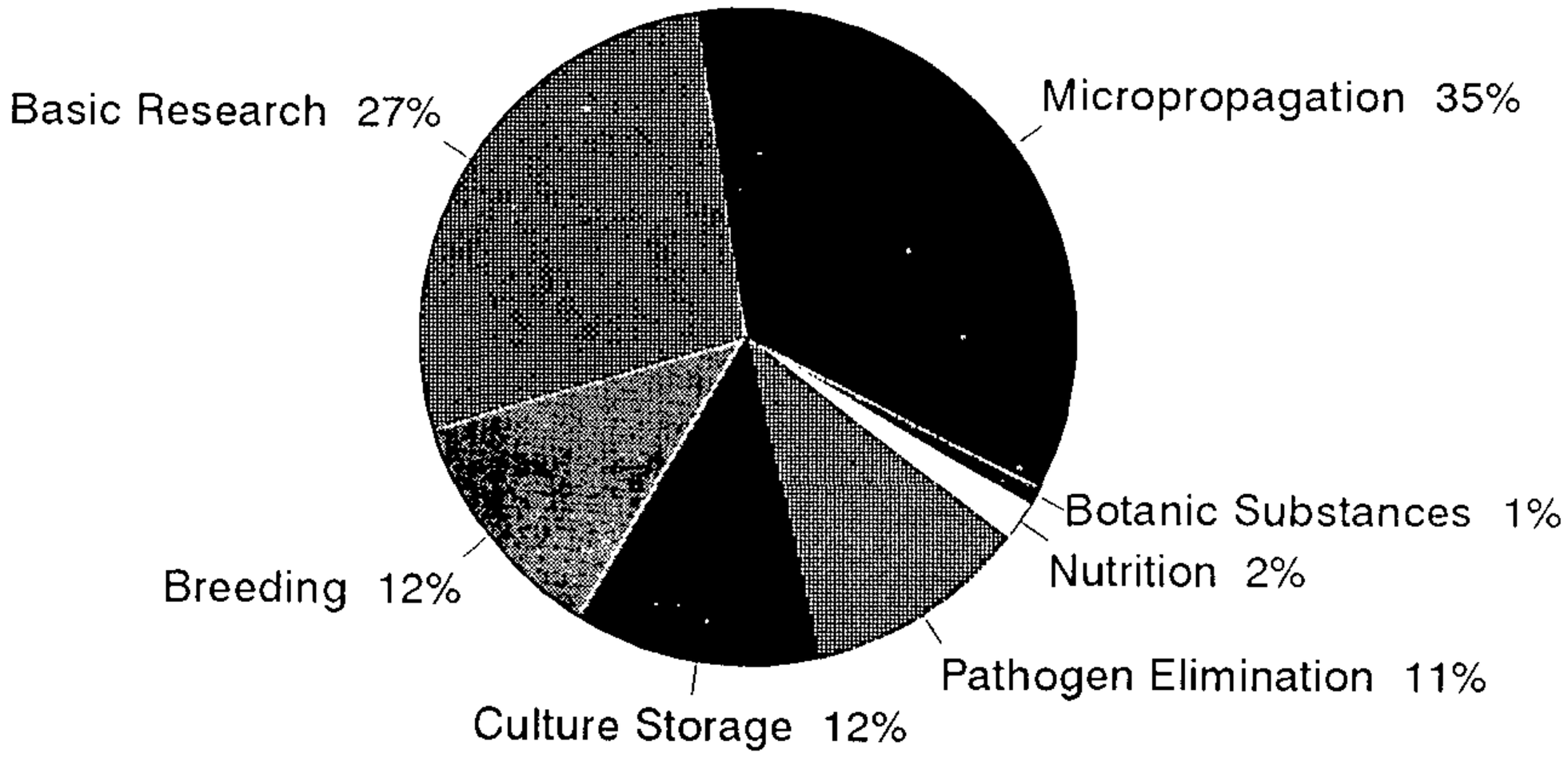

Figure 4. Frequency distributions of laboratory specialties in the U.S.

a "1" next to the specialty if methods were perfected or a "2" if methods are under development. The species of plants were also to be named next to the specialty area where appropriate.

There were 125 laboratories from 32 states which responded to the questionnaire. Figure 1 shows the number of laboratories responding from each state. The 1987 survey stated that the majority of commercial ornamental plant tissue culture laboratories in the U.S. were in California, Florida, Texas, and New York. The top states in this survey were Florida (17), California (15), Connecticut (10), Texas (8), Illinois (7), and Hawaii, Washington, New York (each with 6). Of the responding laboratories, 53% were private, 42% were public university laboratories, and 5% were government laboratories. Of the private laboratories 58% were commercial, 35% were R&D, and 7% hobby. Of the university laboratories 56% were research and 44% were teaching; 90% of the government laboratories were research. Only 22 laboratories responded from Canada; 11 were government, 6 were public university, and 5 were private.

Laboratory sizes in the U.S. ranged from as large as 15,000 ft^2 to 100 ft^2. Figure 2 shows the percentages of laboratories for each of the sizes. The majority of laboratories responding (26%) were between 500 and 999 ft^2. The largest laboratories were located in Florida (15,000, 10,000, and 2 with 4,000 ft^2), North Carolina (10,000 ft^2), California (7,500 and 4,000 ft^2), Tennessee (5,000 ft^2) and Washington (2 with 5,000 ft^2). The largest laboratory in Canada is 10,000 ft^2 and the smallest is 200 ft^2.

Laboratory size could also be viewed by looking at the number of employees. Of the laboratories responding, 6% had 1 employee, 44% had 2 to 5 employees and 26% had 6 to 10 employees (Fig. 3). If the number of full-time employees per laboratory was further broken down, 21% had 1, 48% had 2 to 5, 17% had 6 to 10, 8% had 11 to 20, and 3% had 51 to 100 full-time employees. Of the laboratories with part-time employees, 14% had 1, 66% had 2 to 5, 12% had 6 to 10, 6% had 11 to 20, and 2% had 21 to 50 part-time employees.

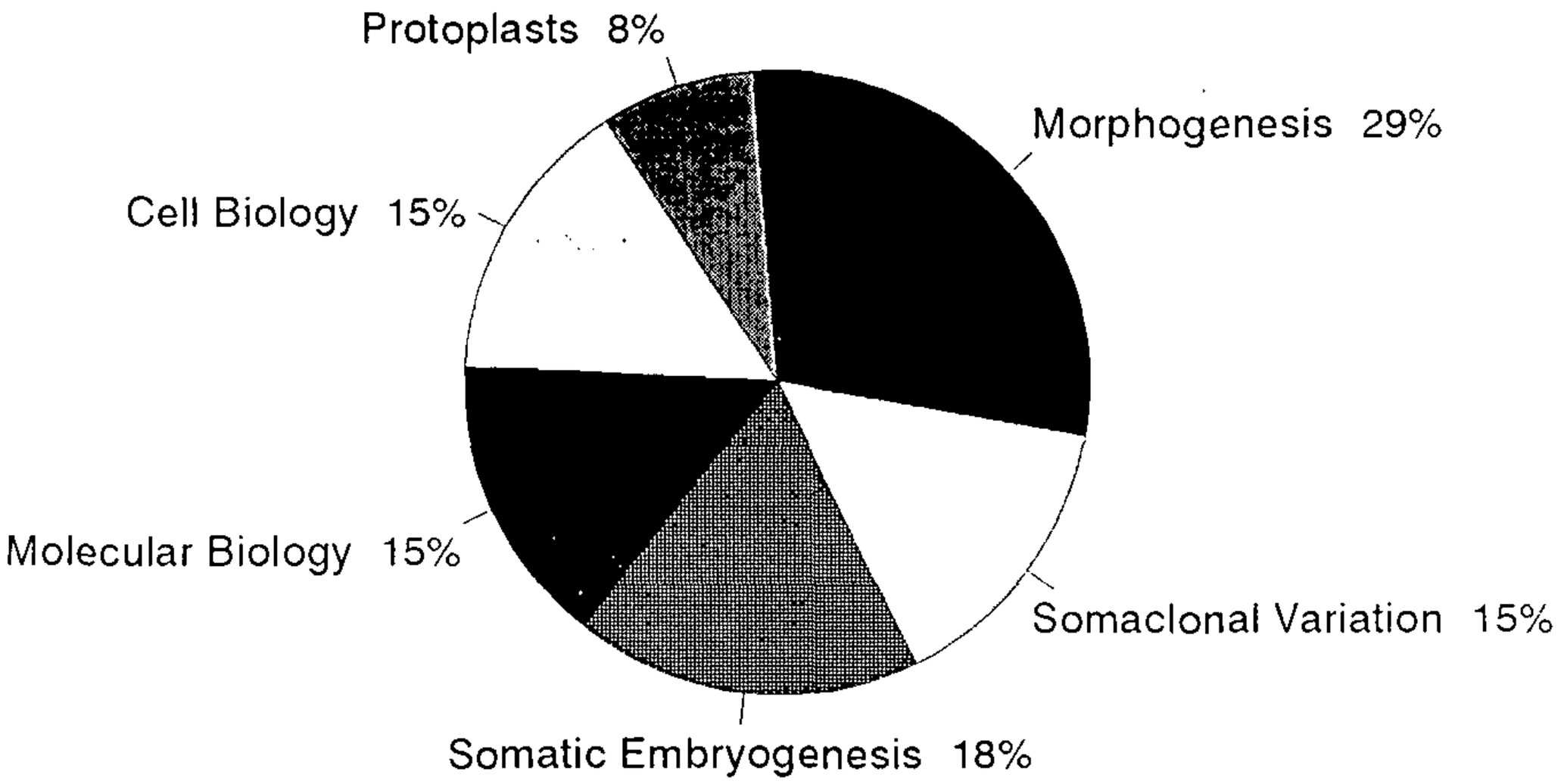

Figure 5. Frequency distributions of basic research programs in U.S. plant tissue culture laboratories

Attempts to identify gender relationships in the responding laboratories were made by examining the names of the laboratory owners and managers. Of the respondents in the U.S., 72% were male and 28% were female. In Canada, 69% were male and 31% were female.

Interests and specialties are difficult to exactly quantify since many laboratories had more than one interest. However, the leading specialty was micropropagation with 35% (Fig. 4). After micropropagation came the group of "basic" research programs which included somaclonal variation, morphogenesis, protoplasts, cell biology, molecular biology, and somatic embryogenesis (Fig. 5). Following basic research, breeding and culture storage were the next largest categories, each with 12%, and pathogen elimination had 11% of the total interest.

Plant tissue culture businesses continue to be misrepresented and misunderstood by economic tabulators. As the value of horticulture has been underestimated in the past when it was "clumped" under the general category of "agriculture", the value of plant tissue culture is currently underestimated. Not until businesses are clearly identified and the products and value of the products are outlined will the industry be fully appreciated. This survey is just the beginning of a lengthy evaluation process.

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TUESDAY MORNING 1 DECEMBER 1992

The morning session was reconvened at 10:30 a.m. with Tom McCloud serving as Moderator.

Evaluation and Propagation of Lacebark Elm Selections by Hardwood and Softwood Cuttings

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The many new cultivars of lacebark or Chinese elm that are being introduced require increased vegetative propagation of the species. Conventional softwood cuttings were used to propagate superior selections. IBA concentrations of 5,000 to 10,000 ppm produced 73% to 93% rooting of wood collected from two mature specimen trees in May and June. Hardwood cuttings taken in February from vigorous young trees rooted up to 100% at 10,000 ppm IBA and established well in the nursery. Rooted hardwood cuttings produced over twice the growth of softwood cuttings taken the same season. Many new selections are under evaluation.

INTRODUCTION

Although lacebark elm (*Ulmus parvifolia* Jacq.) is traditionally produced from seed collected from this autumn-flowering species, the recent surge in introduction of new cultivars necessitates vegetative methods of propagation. The growing popularity of this Asiatic species can be attributed to its wide geographic adaptation; heat and drought tolerance; resistance to elm leaf beetle and Dutch Elm Disease; and its picturesque, flaking bark.

Improved selections include the familiar, but somewhat tender 'Drake', hardy to zone 7; 'Dynasty', from the National Arboretum, selected for its distinct vase shape (Santamour, 1984); and 'King's Choice' (PP 5554), a vigorous type selected at Hamstead, Maryland.

Recent introductions include 'Aross Central Park', reflecting the location of the 100-year-old parent tree growing in New York City (Karnosky, 1988), and two patented selections, Athena™ and Allee ™ (originally named 'Emerald Isle' and 'Emerald Vase', respectively), from the University of Georgia (Dirr and Richards, 1989).

Some cultivars offer the added advantage of fall color, e.g. 'Burgundy' (Dirr, 1990) and 'Pathfinder', a disease-resistant, U.S.D.A. release with grayish-red fall foliage (Higginbotham, 1992). Some new hybrids also possess good insect and disease resistance. Most of these are under evaluation at the Kansas State University, Horticulture Research Center at Wichita, Kansas. Additional clones being evaluated resulted from superior specimens identified by nurserymen and from breeding and selection programs in other states.

Lacebark elm has been shown to root easily from softwood cuttings (Dirr and Frett, 1983; Hickman and Whitcomb, 1983), but limited success has resulted with use of hardwood cuttings. Several advantages are offered by the latter technique, including: (1) winter pruning wood can be utilized, (2) no mist system is required, (3) cuttings can be lined out the same season, and (4) the need for winter protection and storage of potted liners produced by softwood cuttings can be avoided.

MATERIALS AND METHODS

Softwood Cuttings. Availability often dictates time of sticking cuttings. Such was the case when the opportunity occurred to obtain cuttings from the champion Lacebark elm in Garden City, Kansas, and a large specimen tree on the Iowa State University campus, Ames, Iowa. Cuttings were first obtained from the large Garden City tree in late May, 1989 and given treatments of 5,000, 10,000, or 20,000 ppm IBA or Hormodin No. 3 (8,000 ppm). Untreated cuttings served as controls. The highest hormone treatment was not used in later experiments. Short terminal shoots from the Ames tree were provided by Jeff Isles, Extension Horticulturist at Iowa State University, in early June, 1992. Cuttings were prepared from 1-year wood, but occasionally 2-year wood was used to achieve 4- to 6-inch-long cuttings. After lower leaves were stripped, which caused some wounding, cuttings were given a quick dip in 2,500, 5,000, or 10,000 ppm liquid IBA on June 8 and stuck in perlite : peat (70 : 30, v/v) or 100% sand and placed under intermittent mist. Untreated cuttings served as controls. Rooting was evaluated and cuttings were potted on July 16, 1992.

Hardwood Cuttings. Various selections under evaluation at the Kansas State University, Horticulture Research Center, grown from northern seed sources that had shown superior growth and foliage characteristics plus excellent hardiness, were selected for propagation by hardwood cuttings and further evaluation. Terminal cuttings, approximately 6 to 8 in. in length, were taken on February 4, 1991 from several 3-year-old nursery grown trees during a regular pruning exercise. The vigorous growth produced in the previous season gave cuttings averaging approximately 0.35 cm in diameter at the base. Cuttings were untreated (control) or given a quick dip in 10,000 or 20,000 ppm liquid IBA prior to sticking in a perlite : peat medium (70 : 30 v/v) placed over bottom heat of 70°F. The cool greenhouse was maintained at 50°F night temperature, but often reached 80°F in the daytime. Cuttings were misted twice daily by hand and more frequently as leaves appeared. The experiment was repeated in 1992 with a similar group of plants, including 'Dynasty' as a standard.

RESULTS

Softwood Cuttings. In both cases with older trees from Garden City and Ames, softwood cuttings were successful in cloning these mature specimens. Up to 93% rooting occurred with the Garden City tree, but no improvement occurred above 10,000 ppm IBA (Table 1). Therefore, the highest treatment was dropped when propagating the Ames, Iowa tree. Also, the Ames cuttings were placed in 100% sand and perlite : peat (70 : 30, v/v), but because of a shortage of cuttings, the control group was omitted from the latter medium. Hormodin No. 3 (8,000 ppm IBA talc) did not appear to be as successful as liquid IBA. Media did not appreciably affect rooting of the Ames cuttings, although percentages were not as high as those for other cuttings rooted previously. Only 53% rooted in sand at 5,000 and 10,000 ppm IBA, but the percentage increased to 73% at the higher concentration in perlite : peat (Table 2).

Table 1. Rooting of softwood cuttings of lacebark elm from Garden City, Kansas[1]

IBA (ppm)	Rooting (%)	Quality rating[2]
0	51	2.0
5,000	87	3.0
10,000	93	4.0
20,000	83	4.3
Hormodin No. 3	82	2.5

[1] Stuck on May 31, 1989 in Sunshine No. 4, with intermittent mist 6 sec every 7 min.
[2]Rated on scale of 1 to 5 with 5 = most roots (mean of 20 cuttings per treatment).

Cuttings were potted on July 6 in Anderson Die 3-5/8-× 6-in. square containers in Metro-mix 510. Potted plants were grown inside the greenhouse until September, then acclimated outdoors in preparation for winter storage in an unheated polyhouse. Height of the Ames cuttings averaged 12.6 in. at the end of the season.

Table 2. Rooting of softwood cuttings of lacebark elm from Ames, Iowa[1] .

	Sand		Perlite:peat	
IBA (ppm)	Rooting (%)	Roots/rooted cutting	Rooting (%)	Roots/rooted cutting
0	7	1	omitted	omitted
2,500	47	17	53	7
5,000	53	13	40	9
10,000	53	13	73	10

[1] Stuck on June 8 and evaluated on July 16, 1992 (average of 15 cuttings per treatment).

Hardwood Cuttings. Rooting varied from 0% to 100%, depending on treatment, but most selections rooted quite well, especially at the 10,000 ppm IBA concentration. Of the 36 seedlings compared, only two showed improved rooting at the 20,000 ppm IBA concentration. Several rooted from 20% to 50% without hormone treatment, but percentage rooting and number of roots per rooted cutting were consistently best at 10,000 ppm. Cuttings with greater caliper seemed to root best, perhaps because of a greater supply of accumulated carbohydrates in stem tissue, but this trend was not consistent. Not all data are reported, but a representative example of five selections, including 'Dynasty', is shown in Table 3.

Cuttings were sufficiently rooted in 5 weeks to be lifted for potting on March 13. Liners were grown for 2 months in 3 - × 6-in. bands filled with sawdust : peat : sand (3 : 1 : 1, by volume) amended with Osmocote 17-6-10 plus minors at 8 lb/yd^3 plus

dolomite lime at 5 lb/yd^3. Plants were well enough established to line out in nursery rows on May 23, 1991, before the time to begin sticking softwood cuttings (Fig. 1). Additional fertilizer was supplied at the rate of 100 lb of nitrogen per acre using 13-13-13. Growth at the end of the first season ranged from 25 to 38 in. (Table 3). This is over twice the growth made by softwood cuttings, which have to be stored with winter protection for lining out the following spring.

Table 3. Rooting and growth of lacebark elm hardwood cuttings[1].

Elm clone	Source	IBA (ppm)	Rooting (%)	Roots/ cutting	Seasons growth (in.)
C-10	Expt. Sta. Colby, KS	0	0	0	
		10,000	100	4	33.0
		20,000	0	0	
Dynasty	National Arboretum Wash., DC	0	0	0	
		10,000	100	3	27.0
		20,000	20	2	
GC-41	Expt. Sta Garden City, KS	0	0	0	
		10,000	100	7	25.0
		20,000	0	0	
MA-34	Morton Arb. Lisle, IL	0	40	3	
		10,000	100	8	29.5
		20,000	100	6	
MR-17	Morton Residence Wichita, KS	0	0	0	
		10,000	60	4	38.0
		20,000	20	2	

[1]Stuck on February 4, evaluated and potted on March 13, and lined out in nursery rows on May 23, 1991. Growth was measured at the end of the first season.

DISCUSSION

It is recognized that numerous methods of vegetative propagation including budding, grafting, softwood and hardwood cuttings, and tissue culture for some cultivars, can be used to mass-produce this versatile tree. Individual cultivars may vary slightly in their hormone concentration requirement, but 10,000 ppm IBA appears optimum for hardwood cuttings. The technique has worked well on certain selections for 2 years and provides both an easy method and twice the growth of softwood cuttings. A full summer's growth produces plants 2 to 3 ft tall in the same season in which cuttings are taken and avoids the need for winter protection required by softwood cuttings.

Figure 1. Hardwood cutting of lacebark elm ready for lining out by the time softwood cuttings are stuck.

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Grafting Viburnums: New Ideas and Techniques

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The grafting of viburnums is not new. Case Hoogendorn (1952) presented to the second meeting of the Plant Propagators Society a very comprehensive paper. From 1952 to the present, much of the need for grafting viburnums has been diminished by improved rooting of cuttings. However, rooted cuttings of the *Viburnum carlesii* type can still suffer horrendous losses during overwintering and in the transplant phase as a bareroot liner. Mortality rates as high as 60% to 70% for bareroot *V. carlesii* and *V.* × *burkwoodii* can be encountered. Much of this problem can be linked directly to a poor cutting root system. A comparison of the root systems of equal age with bareroot *V.* × *rhytidophylloides* 'Alleghany' and *V.* × *burkwoodii* will show the 'Alleghany' plant to have two or three times the amount of root mass. Transplant losses of 'Alleghany' are virtually nil while those of *V.* × *burkwoodii* can be substantial. For some viburnums, such as *V. carlesii* and *V. carlesii* 'Compactum', grafting can still have an important part in production. McMillan-Brouse's (1970) survey in England included grafting of other viburnums such as *V.* × *rhytidophylloides* 'Fullbrook', *V. bitchiuense*, *V.* × *burkwoodii* 'Chenault', V. × *carlecephalum*, *V. macrocephalum*, and *V.* × *burkwoodii* 'Park Farm'.

Some of the loss problems with rooted cuttings can be offset by grafting onto more acceptable rootstocks. Hoogendorn (1971) used *V. dentatum* and *V. lantana* seedlings as rootstocks for *V. carlesii* and *V. carlesii* 'Compactum'. The problem associated with seedlings is the strong tendency to throw suckers which tends to cause development and maintenance problems. I favor rooted cuttings of, *V. rhytidophyllum*, *V.* × *rhytidophylloides*, or *V.* × *rhytidophylloides* 'Alleghany' as understocks. Others that are acceptable are *V.* × *rhytidophylloides* 'Willowwood', *V. lantana*, and *V.* ×*pragense* (Table 1). Rehder (1986) groups viburnums according to close similarities and I feel that following his classification system for closely related species will indicate others that are equally acceptable as rootstocks.

We begin preparing the rootstocks 6 months to a year in advance. Cuttings are selected from stock plants with the intent of having stems that are at least pencil thick and have a long internodal segment. The base of the cutting is severed from the stock plant just above a bud, so that the lower 1 to 2 in. of the cutting has no auxillary buds. It is not enough to select a cutting with a bud on the basal end and to remove that bud with a knife as the remaining portions of the vascular bundles will sometimes give rise to an adventitious bud. An internodal segment will not do this. Once the top of this cutting is removed, the resultant understock is a stem segment without buds but with a very large root mass. This makes for an ideal non-suckering rootstock. McMillan-Brouse (1970) suggested in his paper that a normally rooted cutting would afford some protection from suckering but isolated cases can still occur. With the technique outlined here, that possibility is eliminated.

Once the rootstock is sufficiently rooted into an individual pot, grafting can commence. Usually the time to achieve an adequately rooted plant is 6 months to a year. There can be no getting around the fact that a thoroughly rooted understock

is of the utmost importance. Most successes or failures in grafting depends directly upon the condition of the understock.

Once the rootstocks are rooted they are overwintered underneath Bubble-Pac as outlined by Barnes (1990). Under Bubble-Pac the rootstock will continue to make new roots all winter long and therefore grafting can start as soon as the rootstocks are brought into the greenhouse in January. There is no need to wait for the understock to form new roots as they will have already done so.

Table 1. Effective combinations for grafting *Viburnum carlesii* and its hybrids.

Understock	Scions
V. dentatum	*V.* × *bodnantense*, *V.* × *burkwoodii*, *V. carlesii*, *V.* × *juddii*
V. dilitatum	*V. carlesii*, *V.* × *burkwoodii*
V. lantana	*V.* × *carlcephalum*, *V. carlesii*
V. opulus *V. setigerum*	*V. carlesii* *V. carlesii* 'Compactum'
V. × *rhytidophylloides* *V.* × *rhytidophylloides* 'Alleghany' *V.* × *rhytidophylloides* 'Willowwood' *V.* × *pragense*	*V. carlesii*, *V. carlesii* 'Compactum', *V. lobophyllum*, *V. prunifolium*, *V. rufidulum*

Scion wood, with all flower heads removed, is normally collected on days that are above freezing and stored in poly bags with moist toweling in a refrigerator at around 40°F. They are removed as needed and allowed to warm to room temperature before grafting. They can be kept for up to 30 days. The type of graft used is a modified side graft which looks similar to a whip and tongue graft. The grafts are tied tightly with ¼-in. rubber strips and are placed directly on the gravel floor of the greenhouse. The grafts are not waxed. Once the grafts for the day are complete, they are covered with 50% white poly. They are held between 60°F and 70°F for about 30 days. After 10 days, they are watered from the bottom by placing full trays in shallow troughs with several inches of water, but not enough to touch the graft union, and they are allowed to take up water until the soil becomes evenly moist. The grafts are then removed and placed back under the poly tent. After 25 to 30 days the poly tent can be removed by gradually venting and reclosing periodically to slowly adjust grafts to a lesser humidity. This acclimation process should take place for about 5 days with the cover being left off completely after the 5th day. The

grafts can be watered sparingly as needed but care should be given so that they are not drenched regularly. Once the grafts begin growth, regular watering and light fertilization (100 ppm N) can begin. It is important to avoid overwatering initially to prevent the buildup of hydraulic pressure against the scion wood.

The plants should remain undisturbed until mid-May or early June when the tops of the understock are removed in stages. This is usually accomplished by removing a third at a time. After the final stage is cut off, the rubber strips can be removed by cutting with a sharp razor on the understock away from the scion. The rubber strips are replaced with a piece of ½-in. masking tape to prevent the graft from coming apart. These plants are then held for another 6 weeks to 2 months before further potting or planting out. Average take should be around 60% to 70%.

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Grafting of Junipers

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INTRODUCTION

I am going to talk about the grafting of junipers. As you know, certain cultivars of plants cannot be propagated economically by seed, layering, cuttings, or tissue culture. As a last resort they are grafted. In the past juniper seedlings of *Juniperus virginiana*, *J. communis*, and *J. scopulorum*, were used. They were disease prone and erratic in seed bed stands. We now use rooted cuttings of *J.* 'Hetzii' as rootstocks. 'Hetzii' has proven to be compatible with all cultivars of *J. virginiana*, *J. communis*, *J. scopulorum*, and *J. chinensis*.

UNDERSTOCK PRODUCTION

We have a stock block of 'Hetzii' plants that we spray and fertilize faithfully so a clean healthy batch of cuttings can be taken in December after some sharp frosts. Cuttings are gathered on a frost-free day, put in poly bags with some snow or water added, and placed in our cold storage. Cuttings are made before December 25 in a normal fashion and stuck in a bottom-heated bench in our greenhouse.

After rooting, they are hardened-off and field planted about the end of May or 1st week in June. The tops are pruned back before the planting material arrives in the field. Snow fence shades are placed over the beds immediately after the planting machine. Normal spraying and cultivation of the plants continue throughout the summer.

In September, the understocks are pruned back. Taking care to make a flush cut (no coat hanger stubs are left), side branches along the main stem are removed for 5 to 6 in. above the soil level. We do this in advance of digging so that wounds on the plants are healed.The rootstocks are dug the last week in October, placed in plastic boxes in cold storage at +2°C for 3 to 4 weeks, and then potted up in clay pots (2¼ × 3¼ in.). Before potting the roots are trimmed and some of the top growth is removed. The roots are swirled into the clay pot and firmly packed with potting soil. Our mix is 3 peatmoss : 2 coarse sand (v/v) and it has some lime, superphosphate, and trace elements in it.

We prefer clay pots because plastic pots need more careful attention – they do not breathe or take up water from the sides as a clay pot does. This is critical because at grafting time no watering takes place.

The potted 'Hetzii' understocks are placed on the greenhouse benches with approximately 4-in. peatmoss underneath the pot and some peatmoss between the pots. The peatmoss in the benches is prepared in advance and wetted thoroughly. The peatmoss is moistened to the point where it is possible to squeeze a little water from a handful of it. After plunging the plants are sprayed with Botran which is then washed into the pots. About the 1st of January the plunged plants have enough root action and we start grafting.

An insertion bulb thermostat with a 2-degree differential is used to monitor bench temperature. Buy the best thermostat — we use Honeywell. Thermostats

get lazy (react slowly) after a while, and too much depends on this instrument. We throw them out after five years. The sensor of the thermostat is placed just under the pots.

GRAFTING

The potted understocks are brought to the grafting area. Choose the straightest and smoothest place on the stem for the graft and make a cut close to the soil and into the stem at a 45 degree downward angle. Then a lengthwise slice is taken out downward to the previous cut. The downward slice is 1¼ in. long. Make sure the vertical cut is straight, not bowed.

We gathered our scions a week to ten days before we started grafting. Fresh scions are best but you can only collect when temperatures are above freezing. The scions are cut 10 to 12 in. long. We put 200 scions in black plastic bags with approximately two cups of water, seal each bag, and then place in refrigerated storage at 32°F until needed. The scions of the desired cultivar are trimmed to 10 in. and lower side branches are removed. A flat cut of 1-3/8 in. long is made and followed by a 45 degree cut on the base. The scion is placed against the cut on the understock, taking care to match the scion and rootstock on both sides. This means that the cambium layers of the stock and the scions match on both sides. One side is sufficient but two is better. The scion is held in place and tied with a rubber band. Then the grafts are returned to the bench and plunged into the peatmoss so the graft union is covered.

The bench is covered with clear plastic suspended over steel bows spaced at 3-ft intervals. This arrangement keeps the plastic off the plants and directs condensation to the sides of the bench. The plastic is sealed tight on both the sides and the ends. The grafts remain covered at least 4 to 6 weeks. During sunny days a white shade cloth is pulled over the plastic. The air temperature must not exceed 100°F because you can cook them at high temperatures even with plenty of moisture. The thermostat for the bottom heat is set at 68 to 70°F and a good soil thermometer is used to monitor soil temperature at the bottom of the pot. A thermometer is also hung inside the plastic structure through a hole to monitor soil temperature.

After 4 to 5 weeks, the plastic is lifted off and the plants are inspected. By this time a callus has developed along the cut edges. At this time, spraying is started with Benlate or ferbam on an alternate basis every three weeks. Airing is begun—just a crack every 8 ft—on sunny days. The moisture content of the peatmoss and soil in the pots must be watched at this point. Water maybe given after the 5th week if needed; however, water only on a sunny day and let the foliage dry off in the afternoon. Covering and shading will now be more frequent as the sun is getting stronger at the end of February and March. After 10 weeks, the 'Hetzii' tops are removed, the grafts are returned to the bench, and the union again covered with peatmoss. The plastic covering and shade cloth are both put back on to reduce shock. Be careful when handling the graft unions, they are still very fragile!

After approximately 15 weeks, the plastic is removed and the shadecloth is left. At this time the bench temperature is lowered to 60°F and then reduced to 50°F by May 1st. By May 15th the heat is turned off, the shadecloth is removed, and more air is given.

FIELD AND CONTAINER PLANTING

The grafts are field planted or containerized the 1st week of June. Grafting rubbers are removed before planting and care is taken to keep the rootballs intact. The plants are set out with the graft union well below the soil level. After planting the grafts are covered with shading for 4 to 5 weeks until new roots grow out into the soil.

Propagation of the Temperate Woody Flora of Mexico

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The floristic affinities between the northeastern U.S. and northeast Asia have been known and studied by botanists for over 100 years. Less well explored is what affinities the flora of northeastern Mexico has to these two regions. Many of the temperate woody genera of Mexico are familiar, including *Cornus*, *Cercis,* and *Ostrya*. It is logical to assume that most were recent arrivals, having migrated southward during the Pleistocene glaciations. However, recent studies of fossil pollens in coal deposits in Veracruz State detected pollen of *Abies*, *Picea*, *Liquidambar*, *Fagus*, *Quercus*, *Ulmus*, *Juglans*, *Populus*, *Alnus*, and *Celtis*. As these deposits were dated to the Middle Miocene we can see that temperate elements in Mexico predate the glacial epoch by 18 million years. This indicates a more complex relationship between the floras of Mexico and other regions than previously thought. It is accurate to think of this flora not only as recent disjunctions but as a separate and distinct flora with a complex history.

Temperate flora, for the purposes of this paper, is defined as plants native to areas which consistently receive temperatures below 25° F., and which are probably cold hardy in Zones 7, 8, or 9 with a few that can survive Zone 6 or colder.

Mexican temperate flora can be found in a number of habitats: alpine zones, subalpine conifer forest, oak-pine forest, deciduous forest, and, most interesting of all, cloud forest. Due to a mountainous terrain (up to 12,000 ft), varied soil types, and rain shadow effects, the mountains of the states of Nuevo León and Tamaulipas have a wide variety of microclimates which encourages species diversity. One drawback to this supermosaic is that plants may be specifically adapted to a narrow set of conditions. The flora of these mountains warrant further testing for horticultural and landscape use and need greater representation in botanic gardens. There are also a number of research avenues which need exploring.

Many species are described briefly including propagation data. For the purposes of this paper "C" will represent a cold stratification (35°F), "W" a warm stratifica-

tion (60°F to 80°F), and the number preceding the letter indicates duration in months.

Abies mexicana is one of the eight firs native to Mexico and is restricted to an area on the border of Nuevo León and Coahuilla. It grows to 65 ft, is broadly conical, and was collected at 8,300 ft altitude. Only 1% germination resulted after 3C (100 seeds).

Acer saccharum ssp. *grandidentatum* was collected in the San Carlos Mountains at 3,400 ft with such genera as *Carpinus*, *Ilex*, *Persea,* and *Staphylea*. It was growing among ridges of granitic rock (rare in Mexico) and reached 50 ft in height. After 3C, 16% germination occurred.

Acer skutchii is a rare maple, related to sugar maple, found in a few locales in Mexico and Central America. Its habit of growth looks exactly like sugar maple but its new growth is bright pink, changing to red. The cloud forest area, where it is native, receives lows in the mid-twenties (F) and 99 in. of precipitation annually. The species grows rapidly, reaching 3 ft in two seasons, and has survived 4°F in Texas. Seed sprouted with no pretreatment.

Amelanchier denticulata is a much branched shrub which grows on dry alkaline soil. Its best ornamental features are its red to lavender fruits and thick small leaves. Ten percent germination occurred after 3C.

Buddleia species. Seed was collected at 9,100 ft on the slopes of Cerro Potosí. No germination resulted after 2C but 2 seedlings germinated after a second cold period.

Carpinus species. Seed of this plant, collected in mid-October, and placed in cold stratification began to germinate in the bag. Upon sowing 65% germination resulted. It had bronzy-pink, doubly serrate new foliage.

Cercis canadensis var. *mexicana* is variable, with selections having hairy or glabrous leaves known. It is found in dry arroyos as well as woodlands. High germination resulted after a hot water soak and 3C.

Clethra pringlei is a rare evergreen tree with long racemes of white, cinnamon-scented blooms. No seed pretreatment needed for germination.

Cornus stolonifera. Ten seedlings germinated after 3C.

Cornus floccosa was found in a mixed deciduous pine forest. Genera in this region included *Liquidambar*, *Nyssa*, *Hamamelis*, *Prunus*, *Sapindus* (130 ft), and *Carpinus*. This species has narrow, pubescent leaves and purplish-black, *C. florida*-like fruits. One seed of 25 germinated after 3C.

Cornus florida var. *urbiniana* possesses large white blooms, the bracts of which hold together to form an open sphere. Red fruit similar to *C. florida* occurs. This plant prefers moist woodland conditions. Seed sown immediately germinated at 48% while 3C yielded 59%. Damping-off was a problem with these seedlings.

A *Crataegus* species was collected at 8,300 ft on the slopes of Cerro Potosí. A new species presently being described, this species forms a compact spherical tree with a single leader. It holds glossy, dark green foliage and quarter-sized red or orange fruit. Lots of 50 seeds were given treatments of 3C, 5W3C, and 1 hour H_2SO_4 followed by 3C. No seed germinated after sowing but following a second 3C lot 1 germinated 20%; lot 2., 6%; and lot 3, 38%.

Diospyros palmeri was a stunted plant in a wind-swept fissure in granitic rock in the San Carlos Mountains. Size of the plant was 5 ft high by 8 ft wide with fruit ripening to a blackish color. Seed sown without pretreatment germinated in 2

months at a high percentage.

Fagus mexicana is a rare tree to 100 ft found only in a few sites in Hidalgo and Tamaulipas States. In Hidalgo, almost pure stands are found with *Magnolia*, *Cyathaea*, *Clethra,* and *Quercus*. After 5C, germination occurred in two weeks.

Garrya laurifolia was given a 3W3C treatment but the seed germinated in the stratification bag during the 3W and were sown.

Hamamelis mexicana is one of the rarest temperate Mexican plants and is only known from a few sites. Its leaf, unlike *H. virginiana* or *H. vernalis*, is tomentose. Only a few pastel yellow flowers were seen. Cuttings collected in April and treated with 8,000 ppm IBA + 1,500 ppm NAA dip, stuck in fine pine bark : perlite medium (80 : 20, v/v), under mist rooted 60%. Seed germinated in low numbers after 5W3C.

An evergreen *Ilex* species tree growing to 75 ft in a moist protected area with *Picea, Abies,* and *Taxus* was collected. Four lots of 100 seed were given treatments of 3C, 3W3C, 6W3C,and 9W3C. No germination resulted after sowing. After a second 3C, lots 1 and 2 germinated at 20% and 2%.

Another *Ilex* sp., a 25-ft tree with thin, willow-like leaves, was collected at 4,600 ft in a cloud forest habitat. Germination treatments (same as for above *Ilex* sp.) resulted in the following: 9W3C yielded 1% germination after direct sowing while lots given 3C and 3W3C again germinated only after a second 3C and yielded germination of 26% and 10%, respectively.

Ilex rubra was found on a wind-ripped ridge in the San Carlos Mountains at 3,500 ft. It has small, toothed, green-black foliage and is judged to be one of the best collections by the authors. A treatment of 3W3C produced no germination. After an additional 3C 32% germination resulted.

Illicium mexicanum is a member of a primitive family, the Illiciaceae, and was collected in a swampy depression in the cloud forest. It has a beautiful magenta-rose ray flower and star shaped seed capsules along with evergreen leaves. Probably a Zone 9 plant at best. Seeds germinated at 60% after 1C.

Juglans hindsii germinated at 16% after 3C.

Liquidambar styraciflua is found as far south as Nicaragua and achieves massive proportions in northeast Mexico. One specimen measured 7 ft dbh. Seed lots of 150 were either sown directly or given 3C and yielded germination of 54% and 73%, respectively.

Litsea sp. sprouted in the stratification bag in the 5W phase of 5W3C.

Lonicera pilosa is a vine honeysuckle with beautiful tubular orange-red flowers collected at 8,500 ft. Heavy germination occurred after 3C.

Magnolia scheidiana can obtain massive proportions, growing to about 100 ft in the cloud forest habitat. Directly sown seed germinated at 3% while seed given 3C gave 7% germination.

Nyssa sylvatica is rare in Mexico and seed has not germinated after treatments of 1C and 3C.

Osmanthus salicifolius was collected at 7,150 ft. Treatments of direct sowing, 3C, and 5W3C yielded germination of 3%, 5%, and 7% respectively but only after another 3C was given after sowing.

Ostrya virginiana is a component of the moist, mixed deciduous forest. Seed lots of 100 seeds were given 3C and 5W3C. Lot 1 had 4% germination while lot 2 had no germination after sowing but following a second 3C yielded 33% germination.

Parthenocissus quinquefolia var. *hirsuta* was found growing in the pine-oak

forest and was notable for its felty leaf and strong red fall color. A treatment of 3C gave 40% germination.

Picea martinezii is one of the rarest spruces in the world and is known only from two sites in Nuevo León. Its cones are among the largest of any North American spruce measuring 6 in. long and 2.5 in. wide. From the northern population, treatments of direct sowing and 3C gave germination percentages of 31% and 32%. The southern, less-populous stand yielded germination of 19% and 13%.

Pinus arizonica var. *stormiae* is a 30- to 60-ft pine which grows on dry slopes up to 9,000 ft altitude. A 3C treatmenta gave 12% germination.

Pinus culminicola is a very rare and endangered pine native to three different mountains (9,750 ft to 11,400 ft) in northeast Mexico. It is a dwarf pinon pine, with a mounding dense habit. It can grow to 15 ft but is usually under 6 ft. This species forms pure dense stands in the subalpine zone but may reach the summit of Cerro Potosi. It has survived outside in Boston for 10 years but is slow growing. A 3C treatment gave a low germination percentage and damping off is a serious problem with this species.

Pinus hartwegii is a large pine to 90 ft with a thick rounded crown. It can be found up to 12,000 ft in elevation. We collected it on the summit of Cerro Potosí in a harsh windswept environment. Jesse Perry, in his fine book "The Pines of Mexico and Central America" suggests that this species may have applications in reforesting high mountain slopes. A 3C treatment produced 50% germination.

Pinus strobiformis is a relative of *P. strobus* and has a wide distribution in northern Mexico. Cones are 8 in. and resinous. It was collected at 8,000 ft. A treatment of 3C gave 50% germination.

Pseudotsuga menziesii var. *glauca*, blue Douglas fir, ranges from interior British Columbia to Mt. Orizaba, Mexico's highest peak. Some taxonomists split off four different species from mexican populations but further work may be warranted. It was collected with *Abies mexicana* at 8,300 ft. A 3C treatment gave 21% germination.

Podocarpus reichei was collected at 4,600 ft in a cloud forest in Tamaulipas. At 23 degrees latitude it is the northernmost stand of Podocarpus in our hemisphere. A tree to 100 ft with leathery 6-in. leaves and a leathery seed subtended by a cherry red aril. The leathery seed coat seems to inhibit germination and once removed, seed germinates readily.

Rosa mexicana is an understory shrub in cool moist pine forests. After 3C no germination resulted but a second 3C produced 30% germination.

Staphylea pringlei was collected in the San Carlos Mountains at 3,100 ft. Twenty-five percent germination resulted after 2C.

Styrax youngae is an understory shrub found on slopes in moist deciduous-pine forests where it is found as a broad 6-ft shrub. It has a felty leaf more similar in shape to *S. obassia* than *S. americanum* which leads us to think there are some species in Mexico that are more closely related to their Asian counterparts than to their U.S. relations. A 20% germination resulted after 3W3C.

Taxus globosa is found sporadically from northeastern Mexico to El Salvador. It can be found as a multistemmed, round-headed, small tree to single-leader trees of 75 ft. Three treatments were tried: 3C, 5W3C, and a 1-hour soak in 1,000 ppm GA_3 followed by 3C. Germination only occurred in lot 2 at 34%. Cuttings collected from 49 plants produced an overall rooting percentage of 89.5% with 11.4 roots per cutting (10,000 ppm IBA dip; 1 sand : 1 perlite, v/v; poly tent).

Tilia houghii seeds (17) were given 5W3C but 5 seeds germinated in the bag during the warm stratification and were sown.

Vaccinium confertum is a low growing, mat-forming *Vaccinium* that reminded some of us of *Gaylussacia brachycera*. Cuttings, treated with 8,000 ppm IBA powder and stuck in sand and perlite (1 : 1, v/v), rooted 100%.

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TUESDAY EVENING 1 DECEMBER 1992

The evening session was convened at 7:30 p.m. with Paul Smeal serving as Moderator.

Composting Leaves for Potting Mix

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At Appalachian Nurseries, we have been composting leaves for over 10 years. We began this procedure more out of service to our local borough than as a possible source of potting media. However, as our compost pile grew over the years, we decided to use it in our potting mix to cut costs. The subject of this paper is how we have developed a low input, low tech, unregulated, low cost method of composting leaves and nursery debris. It has become a win-win partnership for our local municipality and Appalachian Nurseries.

The basics of the partnership are these: we provide the space and the borough of Waynesboro provides the leaves and equipment.

If that sounds simple, maybe that's because it is. I am a firm believer in the KISS theory.

It should be noted that our nursery is located in a medium density residential zone within the borough of Waynesboro. Because we are using only leaves and plant debris in this procedure, the state regulations directing composting of this type in Pennsylvania are minimal and not a problem. There is no paperwork or written agreement; no money changes hands. We both just do our parts. The end result is that the borough saves money on leaf disposal, and Appalachian Nurseries saves money on potting mix. No grid lock here; just cooperation.

Before starting leaf collection in the fall, the borough uses its Hi-Lift to stockpile the previous year's compost. This clears the area needed for the current year's leaves. Total area used is approximately one acre. We windrow the leaves into piles about 100 ft long, 10 ft wide, and 5 to 6 ft high. Throughout the year, we add debris from the nursery—leaves, discarded plants, and used propagating and potting mix. We also allow adjacent neighbors to dispose of grass clippings and yard debris onto the windrow. This, of course, makes good relations and negates any possible objection to the composting. The makeup is approximately 80% leaves (mostly maple and oak), 15% nursery debris, and 5% yard debris. We add lime and some fertilizer to help with the composting. However, we aren't concerned with a fast rate of decomposition, so the amounts we add are not critical. We try to turn the windrows with our own tractor about once a month through the year. Near the end of the year cycle (about August), we combine the windrows two months before the borough comes to stock pile for the year.

After being stockpiled, the compost from any one year will sit for at least two more years before being used. It will continue to break down, but at a much slower rate. Before using it in our potting mix, we hire a contractor to bring in a portable soil shredder and process enough compost for a year's supply. The compost alone contains approximately 10% perlite. We mix additional course perlite at the rate of 1 perlite : 2 compost (v/v) and adjust the pH down to pH 6 with sulfur. The pH of the compost ranges from 7 to 8. We fumigate the prepared mix with methyl bromide, then store it inside until needed. We use approximately 150 cubic yards of this mix per year in our liner production. We pot into 2½-, 3-, and 4-in. pots a broad range of hardy ornamental plants such as *Viburnum*, *Taxus*, *Thuja*, *Chamaecyparis*,

Pinus, *Picea*, *Tsuga*, *Cornus*, *Prunus*, *Forsythia*, *Spiraea*, *Weigela*, and other flowering deciduous shrubs and trees. We do not use this mix for any ericaceous plants such as *Rhododendron*, *Ilex*, *Pieris*, and *Oxydendrum*.

The mix tends to be on the heavy side. Therefore we add composted pine bark (aged Pro Base from Summit, Inc., Louisburg, NC) at the rate of 1 bark : 2 mix(v,v), if potting into pots larger than 4 in. This procedure has enabled us to eliminate buying custom prepared mix and thereby cut our cost of mix by over 50%.

In summary, this procedure works because of cooperation with our local municipality and our ability to take a relatively long time to compost and stockpile a large amount of finished material. There is 800 to 900 cubic yards on hand at any one time. The advantages as stated earlier are: (1) the municipality can dispose of its leaves and save money; and (2) the nursery can generate a constant supply of potting mix and save money.

The Use of Composted Rice Hulls in Rooting and Potting Media

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INTRODUCTION

By 1990 the demand for pine bark, the primary component of our growing media, had risen dramatically. Prices were increasing, and reduced availability became a real concern. Forrest Keeling Nursery sought alternative media components which would be readily available, cost effective, and support good plant growth. Much to our delight aged rice hulls found us. A rice hull is the sheath of the rice grain and is a waste byproduct in rice processing. Once separated the hull is run through a hammer mill having screens 3/16-in. sieve size. The milled hulls are then placed in piles which are composted for a minimum of 18 months. The hulls are then suitable for incorporation into media.

After preliminary comparison testing it became evident that aged rice hulls would support plant growth at least as well as pine bark. A side by side comparison was conducted between our conventional mix (80% pine bark 20% sand) and a mix of pine bark, rice hulls, and sand (2 : 2 : 1, by volume) with 2-gal liners shifted into 5-gal containers. Across the board the oaks, maples, ornamental pears, crabapples, locusts, and others did at least as well in the rice hull containing mix. In addition to the good plant performance, aged rice hulls compared favorably in terms of cost and were readily available.

PHYSICAL CHARACTERISTICS OF RICE HULLS

As received the physical characteristics of the composted rice hulls are as follows:

- A pH of 5.4 to 5.7 is typical among the samples evaluated.
- A porosity as we measure it is in the range of 30%.
- A water holding capacity of about 56% of the dry weight.
- A good balance between drainage and water holding capacity exists as determined by actual crop production. When starting with a dry rice hull containing mix, initial wetting is improved with surfactants.
- Rice hull particles range in size from less than 1 mm to about 3 mm. By weight about 70% of the rice hulls are 1 to 2 mm, with 10% larger and 20 % less than 1 mm.
- Contraction and expansion of media is negligible when compared to peat based mixes.
- Breakdown of rice hulls in media is minimal and is suitable for long term crops. This reduces the need to compensate for watering and fertilization due to media changes.

We have not measured cation exchange capacity (CEC) of this aged material. It is recognized that non-composted rice hulls have a low CEC. Whether the CEC of rice hulls increases with the aging process needs to be determined.

PLANT PERFORMANCE AND PEST PROBLEMS

We have to date observed that plants perform as well or better in mixes containing rice hulls, when compared to any mix not containing rice hulls which we have used. Specific observations include:

- Plants from seedling transplants, direct stuck cuttings, and bench grafts develop an excellent root structure.
- The incidence of damping-off seems to be reduced in a rice hull based mix.
- A rice hull based medium tends to dry at the surface which reduces moss and algae buildup.
- Fungus gnats while still present seem to be less common, and this is certainly an aspect which warrants further evaluation.

CONCLUSIONS

Composted rice hulls are a suitable substitute for pine bark throughout our production program. Rice hulls compare favorably with other media component choices based on direct cost, availability, and uniformity of the product. Based on our observations they may offer indirect savings from reduced microbial and insect pests, and certainly reduced cost when substituted for more expensive media components such as peat moss.

Is Eastern Europe a Useful Source of New Landscape Plants for the Midwest?

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INTRODUCTION

Climatic extremes and unfavorable soils limit landscape plant diversity in the midwestern U.S. Since 1983, I have coordinated the NC-7 Regional Ornamental Trials (Widrlechner, 1990) for evaluating new landscape plants in the region and for increasing the future diversity of well-adapted plants found in commerce. I acquire, propagate, and distribute promising new plants for long-term testing at 38 sites representing the region's climates and soils.

Plants for testing can come from breeding programs or public gardens, but often originate from wild collections. Selecting promising plants for testing from the native woody flora of the temperate world is not simple, especially when many species are poorly adapted to our region. Fortunately, past experiences from the NC-7 Trials may increase the likelihood of future success. For example, populations of trees and shrubs collected in the former nation of Yugoslavia were distributed for testing in the mid-1970s. Analyses of the performance of 27 of these populations in relation to climatic conditions at test sites (Widrlechner et al., 1992) may help answer the question "Is eastern Europe a useful source of new landscape plants for the midwest?"

PERFORMANCE OF INTRODUCTIONS FROM YUGOSLAVIA

Of 27 populations evaluated in seven midwestern states, about one third survived and generally performed well throughout the region; another third failed at the colder or drier test sites; and the remaining third failed at all sites. Statistically significant multiple-regression models, based on both low winter temperatures and moisture conditions at test sites, explained 84% of variation for first-year survival and 56% of variation for overall survival across all sites (Widrlechner et al., 1992). Three measures of low temperature (long-term January means, average minima, and the proportion of years with minima $\leq 32^{\circ}C$) were examined with similar results. Long-term, January mean temperatures were readily available and models incorporating those data were not significantly different from models based on extremes. Moisture conditions were estimated by Mather and Yoshioka's (1968) moisture index, based on the ratio of annual precipitation to potential evapotranspiration.

Evaluation results suggested that climates at collection sites did not correspond well to conditions at test sites and that future explorations in eastern Europe could be more productive if directed to areas with more suitable climates. Four specific criteria for directing future exploration were developed to identify such sites. My report applies these criteria to eastern European conditions and identifies sites with suitable climates.

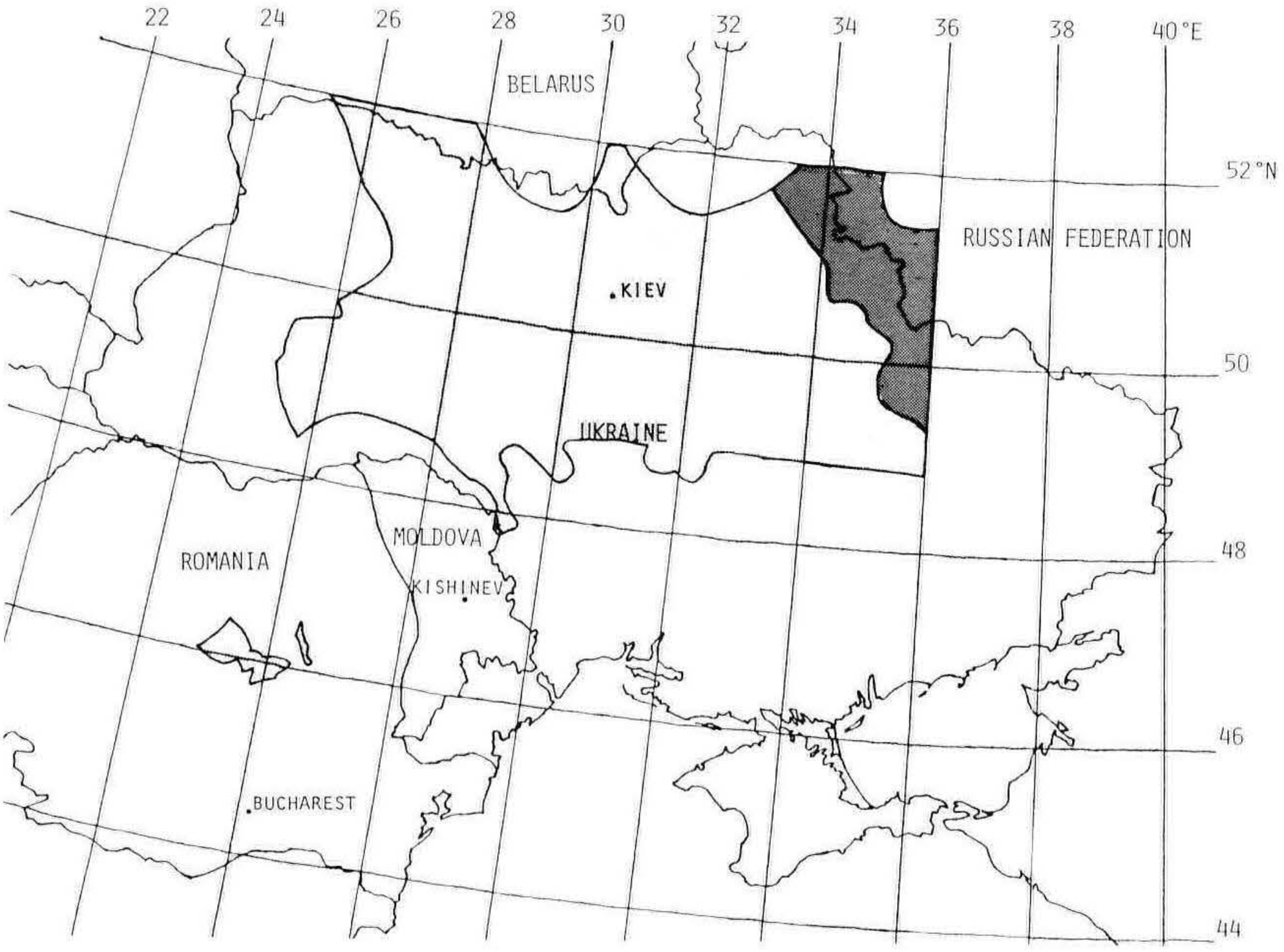

Figure 1. January mean temperatures within climatically-suitable areas in eastern Europe. Light shading: -5 to -7.5°C; medium shading: -7.5 to -10°C.

PROMISING CLIMATIC REGIONS IN EASTERN EUROPE

Eastern European sites with woody plants better adapted to the midwest than those from Yugoslavia should have: (1) January mean temperatures (T_{Jan}) ≤ 5°C; (2) moderate, annual moisture deficits; (3) July mean temperatures (T_{Jul}) $\leq$ 18°C; (4) elevations $\leq$ 1,000 meters (Widrlechner et al., 1992). These four criteria were measured in a region bounded by 18 to 36°E longitude and 44 to 52°N latitude. The western and southern borders were set from temperature data. All sites south or west of the borders, with $T_{Jan} \leq 5$°C, were high elevation sites or had excessively cool summers. The northern border was set at 52°N to account for differences in photoperiod between northern regions and those of middle latitudes. Many woody plants from high latitudes are poorly adapted at lower latitudes having shorter photoperiods during the growing season (Pauley and Perry, 1954; Maynard and Hall, 1980). The eastern border roughly corresponds to Komarov's southwest Russian floristic region as presented by Tutin et al. (1964). As one travels east from this region, the composition of the local flora gradually shifts from a European flora to one with affinities to the Caucasus and central Asia. The four criteria listed above were based on the performance of Yugoslavian plants and may not apply to species from the Caucasus or central Asia that evolved under different climatic or edaphic conditions.

Mean temperature and precipitation data for eastern Europe were obtained from the *Climatic Atlas of Europe* (1970). Since this source did not have an 18°C isotherm

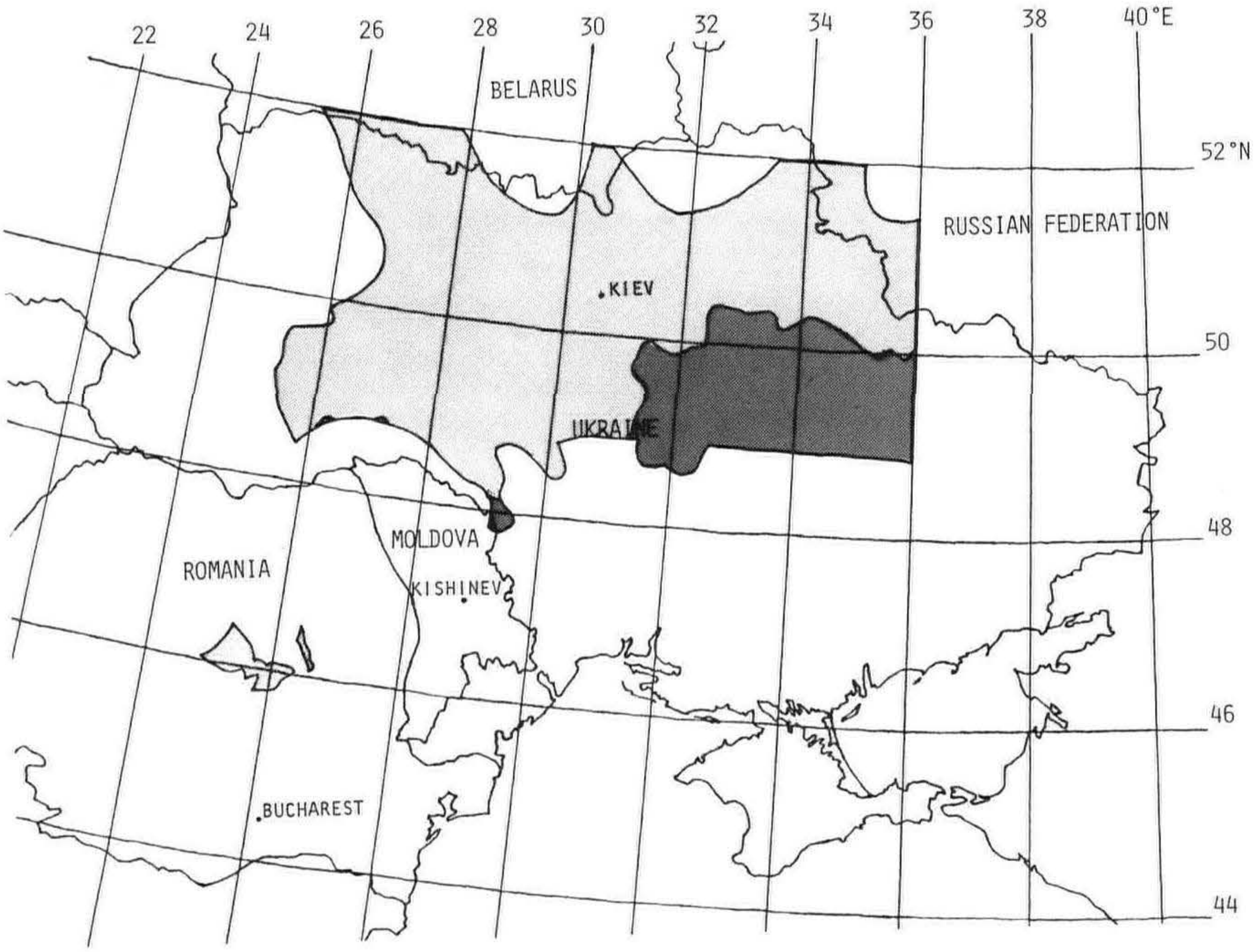

Figure 2. July mean temperatures within climatically-suitable areas in eastern Europe. Light shading: 17.5 to 20°C; medium shading: 20 to 22.5°C.

for July, a 17.5°C isotherm was substituted. Moisture indices were computed by comparing precipitation data to Thran and Broekhuizen's (1965) map of potential evapotranspiration. Indices of 0 to -30 were used to meet the recommendation of a moderate deficit: -30 was the lowest moisture index found at any test site in the earlier study. Elevation data were taken from the *Times Atlas of the World* (1975).

From this analysis, much of Ukraine, and adjacent portions of Belarus, the Russian Federation, and Moldova met all four conditions, as did two small areas in the foothills of the southern Carpathian Mountains in central Romania. Figures 1 to 3 illustrate T_{Jan}, T_{Jul}, and moisture indices for these areas. These areas have T_{Jan} from -5 to -8°C, comparable to winter conditions at Rockford, Illinois or Fort Wayne, Indiana, have T_{Jul} from 17.5 to 21°C, which are somewhat cooler than either Rockford (22.8°C) or Fort Wayne (23°C), and have moisture indices similar to much of the northern Great Plains. There are no perfect climatic analogs in the midwest possessing these eastern European conditions. Temperature analogs can be found at Milwaukee, Wisconsin or Flint, Michigan, but such locations are more moist than the eastern European counterparts.

OTHER CONSIDERATIONS

The criteria tested here would be worthless if areas meeting those criteria were grasslands lacking useful woody plants. Apparently, these areas do include mixed and deciduous woodlands, grasslands, and transitional communities (Pergamon

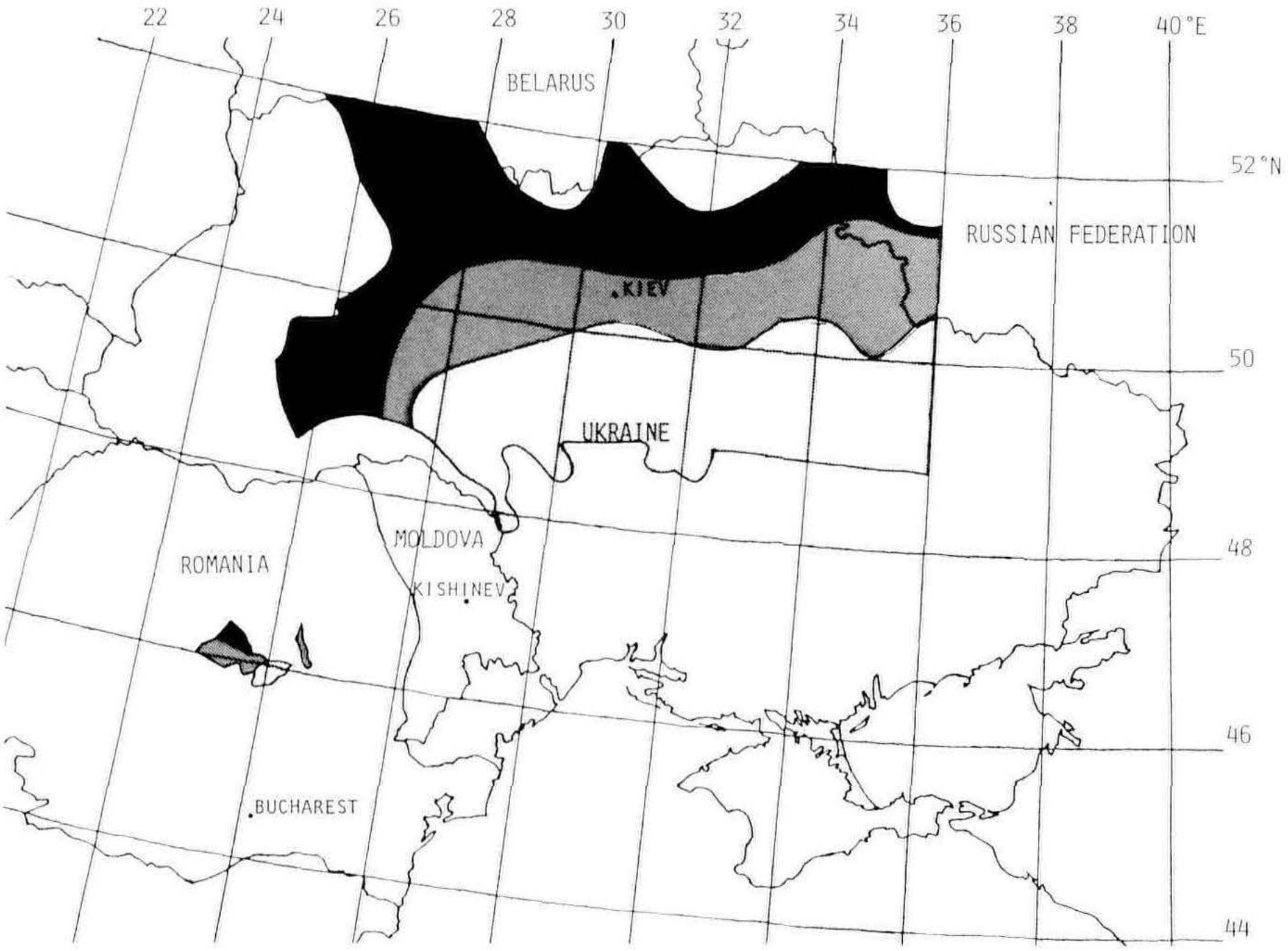

Figure 3. Moisture index, measured as 100|(annual mean precipitation / potential evapotranspiration)-1|(Mather and Yoshioka, 1968), within climatically-suitable areas in eastern Europe. Dark shading: 0 to -10; medium shading: -10 to -20; light shading: -20 to -30.

World Atlas, 1968), similar to natural plant communities in Minnesota and Wisconsin, where coniferous forests, deciduous forests, and prairies are in close proximity (Küchler, 1964).

The final steps to locate promising collection sites rely on analyses of species composition and soil types. Which species found in the climatically-suitable region are good candidates for introduction? European species, such as *Acer campestre* and *Ligustrum vulgare*, are widely grown in the United States but are poorly adapted to much of the midwest. Collections from the northeastern part of their native ranges may be better adapted to our region. Of course, there is also need for caution. If climatic analogs are matched too well, introduced plants could be so well adapted that they might invade natural plant communities. Soils should also be examined. Are the soils at these sites poorly-drained, alkaline, or calcareous? Such sites would be of particular interest both in dealing with the challenges of urban substrates (compaction and calcareous inclusions) and of native, prairie soils. Once these questions are addressed, we may then discover how useful eastern Europe can be as a source of landscape plants for the midwest.

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Market Driven Plant Selection and Production—From Sales Representative or Customer Input

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Part of Bailey's Mission Statement is the committment to produce a broad selection of plant material. Trying to predict the plants that will be popular 4 to 5 years into the future is a challenge. Even the experts in any field can miss the mark. We don't have a crystal ball or use a fortune teller. Several sources of information are used to select new plants. A major source of input at Bailey Nurseries is sales representatives.

At Bailey's, a scheduled week-long meeting (the Plant Planning Meeting) held in late fall gives some insight on what to grow for future catalogs. New plants, market trends, and production schedules are discussed at that meeting. A cozy group of about 20 from sales, administration, inventory, and production attend. One month prior to the meeting, each sales representative submits a list of five plants for review. I title mine, "The Plant Wish List". Plant descriptions, pictures, and at times samples are sent to the office. When 'Reliance' grape, a new hardier seedless grape from Arkansas State University was being considered, I sent fruit for sampling. Not only was it added to our catalog, but the representatives who can use it in their territories have endorsed it. With 14 sales representatives, the new plant list can be extensive. From all this data, Don Selinger and Jim Stolzenburg in Planning and Administration compile an orderly list by category such as fruits, trees, shrubs, roses, vines, etc., and a meeting agenda. The 1993 Plant Consideration List is ten pages long. It includes new and carryover plants from previous years.

The first part of the meeting is devoted to new plant considerations. Each sales representative presents their plants. Their merits and weaknesses are discussed. Topics discussed are the plant's sales range. The production staff addresses the realistic questions of:

- How to grow—seed, cutting, graft, or bud?
- Should it be container grown, bareroot, or both?
- Where to grow—Minnesota, Oregon, Washington—and which location best suits the plant's cold, heat, and soil requirements?
- Sources of stock are suggested. If it is to be budded, we need bud wood from the original or an accepted source. For softwoods, we purchase stock plants or rooted cuttings.
- Are royalties needed to be paid to the appropriate patent holder and do patent tags need to be secured?
- How many to grow or should it be trialed for further evaluation? If a plant is trialed, a quantity of about 500 liners will be grown.

Input comes from all attendees and the discussion is often lively and always informative. Basically, if a sound argument is presented with logic and facts, the

chances are good that the plant will be added to the production schedule. But if it doesn't, there is always next year to present the plant again. Once a plant is placed on the planting schedule, it is the responsibility of administration and propagation to get it into production.

On the 1992 Plant Consideration List were 236 new plants and carryovers. Out of these, 77 were added to the planting schedule and 61 (25%) were actually placed into production by propagating or purchasing.

Four years ago when I started at Bailey's, the majority of my territory—Missouri, Kansas, Oklahoma, southern Illinois, and Arkansas—was a new area. It was apparent that new plant material needed to be produced for this region—but what plants? Being a native of Missouri, I was familiar with several. To expand my list, I asked a lot of questions of customers and potential customers. They are always willing to suggest their favorites. I talked to staff at local botanical gardens, and researchers such as Dr. John Pair of the Kansas State Horticultural Research Center and Dr. David Hensley formerly of Kansas State University, about what plant material was needed in their area and why. The bulk of information for plant selections and trends is gathered during sales calls to customers. New plants can be spotted during a tour of the sales lot, growing fields, or even while driving. *Rhus typhina* #92-8 is a yellow fall-colored staghorn sumac found by Jim Stolzenburg along a Minnesota highway. It is currently being trialed.

Sometimes a suggestion can be a common plant, but offered in a new way. An example is fernleaf buckthorn, *Rhamnus frangula* 'Asplenifolia' in tree form. This came from a customer who uses it as an alternative to threadleaf Japanese maple, *Acer palmatum* dissectum group, where winter kill is a problem. 'Tina' crabapple, *Malus sargentii* 'Tina', is a popular dwarf crabapple that we grow on a 42-in. standard. However, customers have requested it in its natural habit, so this will soon be available. Trade journals and horticulture books are another source I use.

As sales territories have expanded further south and west, a new set of questions are guiding new plant selections. At Bailey's the major question asked of any potential plant addition used to be—how cold hardy is it? This is still an important consideration, but now the questions of heat tolerance and regional suitability are also being addressed. Tatarian maple, *A. tataricum*, is an example. It is very similar in habit and appearance to Amur maple, *A. tataricum* ssp. *ginnala*, but it is more heat tolerant and alkaline soil adaptable. 'Caddo' sugar maple, *A. saccharum* 'Caddo', is a sugar maple we are trialing for heat tolerance and adaptability for the Great Plains. It is a southern ecotype native to Caddo County, Oklahoma. Xeriscape plants are being increasingly requested. This past year has shown that water restrictions resulting from drought can happen in any area of the country. Apache plume, *Fallugia paradoxa*, shrub bushclover, *Lespedeza bicolor*, and some ornamental grasses are examples of xeriscape plants that have been added. The demand for dwarf colorful plants, suitable for small yards such as condominiums and planter boxes, continues to remain strong. Examples include: dwarf doublefile viburnum, *Viburnum plicatum* f. *tomentosum* 'Newport', which becomes 3 ft tall by 5 ft wide; Norman spirea, *Spiraea japonica* 'Norman', which has a darker pink bloom than 'Little Princess' spirea plus a maroon fall color; and Fairy Queen spirea, *S. trilobata* 'Fairy Queen', which becomes 3 ft tall and 3 ft wide, and has a long blooming time. Butterfly bush, *Buddleja davidii*, is popular for its long blooming period and colorful blooms that butterflies cannot resist. Retail customers are wanting unusual plants

such as dwarf Korean lilac tree,*Syringa meyeri* 'Palibin'; weeping pussy willow tree, *Salix caprea* 'Pendula'; and *Prunus cerasus* 'Sparkler' montmorency cherry. 'Sparkler' is a new introduction this year. It is a weeping, spur-type, montmorency cherry from Fruitland Nursery in Idaho. These are all results of customer requests.

When a new plant become available to customers, a follow-up on acceptance and any growing problems is given by the sales representatives. Often the plants are trialed in our own yards. This supplements observations during production. Ivory Halo™ dogwood, *Cornus alba* 'Bailihalo', a compact and finer textured selection of variegated dogwood, and Emerald Carousel™ barberry, *Berberis* 'Tara', a cross between Japanese green barberry and Korean barberry, are recent introductions. Early feedback from customers indicates that they will have a wide appeal.

After the new plants are considered, the rest of the week is devoted to plant production quantities. Input from the sales representatives on trends and future demands helps determine whether to increase, decrease, or even drop from the growing schedule a certain plant. This is a slow but necessary part and continues into the following week or weeks as needed.

The Plant Planning Meeting is the opportunity for sales representatives to relay the information we have gathered from our customers. We are the eyes and ears of the nursery. However, we are only one source used for new plant selections. Additional information is gathered through our own selections, association with other nurseries, universities, arboreta, and plant groups such as the Canadian Ornamental Plant Foundation (COPF) and the Metropolitan Tree Improvement Alliance (METRIA). All of this, helps Bailey's keep abreast of what our customers expect from us today and in the future.

Eight Witches'-Brooms of *Acer palmatum* and Their Propagation

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INTRODUCTION

This discussion would not be complete without mention of the splendid work by Alfred J. Fordham, former research horticulturist at the Arnold Arboretum, Jamaica Plains, Massachusetts. His publication of June 23, 1967 titled "Dwarf Conifers from Witches'- Brooms" gives an historical picture of brooms in U.S.A. and Germany. This publication is a fine landmark treatise of broom theory, combined with the practical side of collecting, growing, and evaluating brooms at Arnold Arboretum.

William G. Schwartz, a Philadelphia attorney and nurseryman (Green Mansions Nursery, Media, Pennsylvania), has been my associate in locating and growing *Acer palmatum* brooms, also called bud-sports. The brooms mentioned are from both our collections. He is constantly sending me up the tree to procure scions at the risk of my life. He states, "Dick Wolff, a retired pilot, should have no fear of height."

In this paper I will be presenting information on eight of seventeen Japanese maple brooms in my collection. I will discuss growth rate; node spacing; terminal growth; spring, summer, and fall leaf color; leaf shape; and strengths and weaknesses of the individual broom cultivars.

BROOM CHARACTERISTICS

What are similar and constant characteristics of most *A. palmatum* brooms?

- A smaller leaf size, usually 30% to 50% smaller than leaves of the parent plant.
- The center lobe on most leaves of brooms is reduced in size. This characteristic varies in the different cultivars.
- They are never found on the highest limbs of the tree, but rather in the mid to lower portions of the tree.
- Most brooms are found on the southeast side of the parent tree.
- Until last month, no broom had ever been found with seed on it. However, a broom bearing mature viable seed was spotted by Mr. Schwartz in the Germantown section of Philadelphia. We obtained seed to be cold stratified and planted out.

We have completed three generations of grafts with no noticeable change in leaf size, shape, node spacing, or terminal growth. These appear to be constant factors not influenced by propagation.

The hardiness of these eight brooms varies. The least hardy is 'Baby Lace' which, when in a container, must be overwintered in a non-freezing (preferably underground) cold frame or root cellar. Most hardy are 'Shaina' and 'Tiny Tim'. Both have been field tested for several years in Zone 6 with no apparent damage.

BROOM CULTIVARS

The eight brooms I will discuss are: 'Shaina, 'Tiny Tim', 'Skeeter's', 'Baby Lace', 'Wolff's', 'Daniel', 'Elizabeth', and 'Mini Mondo'.

'Shaina'. I located this broom in an enormous old 'Atropurpureum' in the Villanova section of Philadelphia. In January, 1984, I procured scion wood and named the cultivar. The parent tree of 'Shaina' was estimated to be over 100 years old with a diameter of 40 in. and a height of 48 to 50 ft. The broom was at the 30 ft level, round, compact, and was approximately 15 ft in span. New grafts are winter hardy after the second year in Zone 6. Color is red—holding red most of the season. Propagated plants are globe shaped with a node spacing of 1 to 2 cm. Terminal growth per year is 5 to 10 cm with average of 7 cm.

'Tiny Tim'. I located this broom 5 years ago on an old tree of reduced vigor in Philadelphia's Fairmount Park section. Color is a pleasant green until fall when leaves display yellow and red color after the first hard frost. Indented center lobe is displayed on most leaves. Node spacing is 1 to 3 cm. Growth with fertilizer was 18 to 20 cm. I named this cultivar in 1988.

'Skeeter's'. This broom is from the cultivar 'Bloodgood' and found and named in about 1986 by Edward Rodd of Rarafolia Nursery in Kintersville, Bucks County, Pennsylvania. Summer and fall colors are the same as 'Bloodgood'. Node spacing is 4 to 5 cm. Leaf is one-half the size of the parent tree. Terminal growth is 6¼ to 9 cm per year.

'Baby Lace'. So far this tree represents the first dissectum type that I have seen. It was found in central New Jersey about 1989 by Edward Rodd who also named it. 'Baby Lace' has nodes 2 to 3 cm apart. Terminal growth is 5 to 8 cm per year. The leaf and broom are very fragile. Potted grafts are not winter hardy and must be protected in a frost free root cellar for the first 3 to 4 years. Leaf size is 3 to 5 cm and very finely divided. Leaf color breaks red but quickly goes to green, then to orange-red for its fall color.

'Wolff's'. This broom was found in Delaware County, Pennsylvania by William G. Schwartz about 1989 and named by him. Leaf color is red in spring quickly changing to green by July. As cool air of fall arrives, it changes to orange-red. Some cascading of the branches has been noted on 3-year-old trees. Node spacing is 1 to 3 cm and terminal growth is 8 to 12 cm. Broom on parent tree is well rounded, compact, and about 8 ft in diameter. Winter hardy after second year in Zone 6.

'Daniel'. This broom was located by Mr. Schwartz around 1988 in the Germantown section of Philadelphia, Pennsylvania and he also provided the cultivar name. The broom is on a very large tree. Fall color is yellow suggesting that the summer color is green. The parent tree was judged to be well over 100 years old. The broom was located at 30 ft, halfway up the tree on the southeast side. Small brown leaves 3½ cm wide were still clinging to the branch. This broom differed from all previous brooms in that leaves had no size reduction of the center lobe and also contained seed. Broom shape was flat and horizontal unlike all other brooms that were globe shaped. Nodes were 2 to 3 cm and terminal growth is 8 to 10 cm per year.

'Elizabeth'. This cultivar was found and named by Edward Rodd of Kintersville, Pennsylvania about 1988. Leaves measure 2 to 2½ cm with typical indent of center

lobe. Petiole length is from 2 to 2½ cm and node spacing is 1 to 2 cm. Leaf color is red. Size, shape, and age of parent tree unknown.

'Mini Mondo'(small world). This is one of the smallest and slowest growing brooms. I discovered it at our Lima, Pennsylvania, nursery 17 years ago and named it. It came from *A. palmatum* "Littleleaf" which is also a selection of mine. Recognition was immediate due to dwarf habit and small leaf approximately 2¼ cm in width. Leaf swirl and pink chimera observed in the wood in 1978 and 1980. By 1986 plant was 3 ft tall. Head is round and compact. Leaf color is green in summer, changing to deep-red color in fall. Indented center lobe present. Ideal for bonsai work.

The following is a list of other *A. palmatum* brooms I have and their parent tree identification.

'Fjellheim'. Parent: Sango-kaku; found in Australia.

'Matthew'. Parent: Green seedling; found by W. G. Schwartz in Drexel Hill, Pennsylvania and named by him.

'Schmidt'. Parent: 'Oshio-beni'; found by J. Schmidt in Boring, Oregon about 1987.

'Verkades'. Parent: Green leaved plant; found by Verkades Nursery, Wayne and Bridgeton, New Jersey.

'Coonara Pygmy'. Parent: Green plant; found and named by A. Teese in Victoria, Australia.

'Englishtown'. Parent: Red fastigate form; found by Stephen Kristoff in Englishtown, New Jersey.

'Royal'. Parent: Unknown; found by Joseph Stupka in Neshantic, New Jersey.

'Kandy Kitchen'. Found and named by Joseph Stupka, Stupka Nursery, Poulski, Pennsylvania.

PROPAGATION

We mainly use a side graft but have used a cleft graft. At times, due to closeness of the nodes, it often becomes necessary to cut through a node to get sufficient surface for the graft. On some of the smaller diameter grafts, considerable skill is required to match scion to understock and wrap with very narrow rubber strips. A wax dip follows and then the grafts go immediately to the growing greenhouse constantly maintained at 60°F. Grafts are watered every second day. In all of the grafts of new brooms, a bulge or swelling of the scion portion of the graft appears.

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Propagation of *Ligustrum vulgare* L. by Forced Softwood Cuttings

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INTRODUCTION

A forcing solution containing 200 mg 8-hydroxyquinoline citrate (8-HQC) per liter and 2% sucrose has been demonstrated to be an effective means to produce softwood growth that can provide quality explant material for *in vitro* studies and micropropagation during the winter dormant season of woody species (Read and Yang, 1985; Yang and Read, 1989). The success of this method encouraged us to attempt to modify explant response by incorporation of appropriate growth regulating chemicals into the forcing solution (Read and Yang, 1989). The purpose of this report is to illustrate how this approach can be successfully adapted to propagation by softwood cuttings.

MATERIALS AND METHODS

The basal one-third of 22-cm long dormant stems of *Ligustrum vulgare* L. were surface disinfested by immersion in bleach solution (0.78% NaOCl) plus 20 drops of Tween-20 per liter for 15 minutes. Then stems were rinsed with distilled water for about two minutes; freshly cut to remove about 0.5 cm from the base; and placed in forcing solutions containing 200 mg 8-HQC per liter and 2% sucrose, to which various plant growth regulators had been added. GA_3, IBA, NAA, and IAA were included separately at 0, 1, 10, or 50 mg per liter of forcing solution in order to determine their effect on the rooting response by the resultant softwood growth. GA_3 and IBA were also added sequentially to the forcing solutions (GA_3 for the first 3 days and then IBA until shoots were cut for rooting). Every three days the solutions were replaced with fresh aliquots of the test solutions and approximately 0.3 cm was cut from the base of each stem being forced. The softwood outgrowths to be used for cuttings were removed when they reached 8 to 12 cm in length and were rooted in vermiculite under intermittent mist at 28°C/21°C day/night and 10 hours of natural daylight in the Horticulture Department (Nebraska) greenhouse. No rooting compounds were applied to these softwood cuttings.

Table 1. IAA in the forcing solution enhanced subsequent root initiation for the forced softwood cuttings of *Ligustrum vulgare*.

	IAA (mg/liter)			
	0	1	10	25
Root number/cutting	5.1	9.3	20.5	14.5

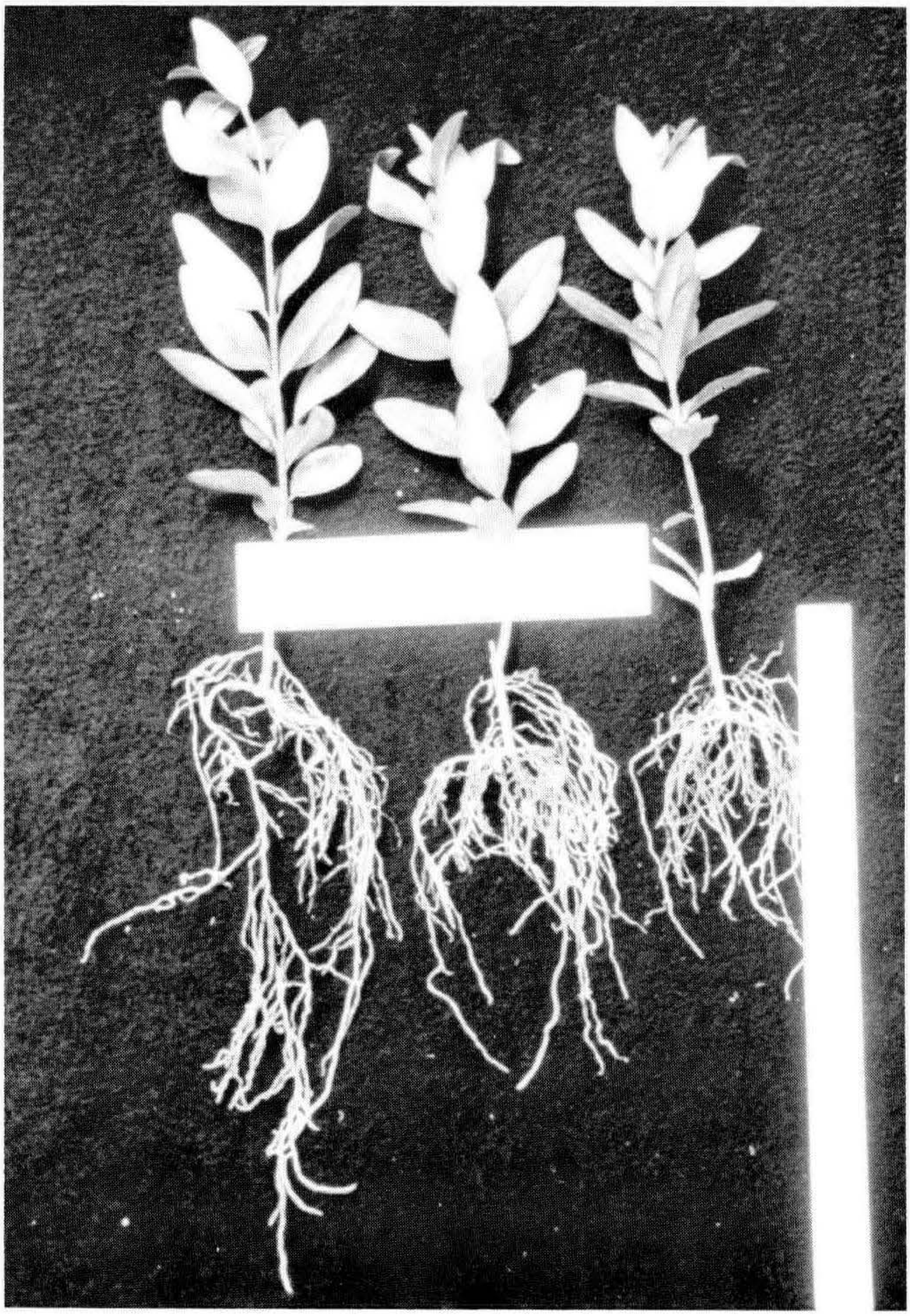

Figure 1. Influence of GA_3 in the forcing solution on rooting of softwood cuttings of *Ligustrum vulgare* L. Left, 1 mg GA_3/liter; middle, 10 mg GA_3/liter and right, 50 mg GA_3/liter.

RESULTS AND DISCUSSION

Inclusion of GA_3 in the forcing solution hastened bud break and promoted shoot elongation as expected (Yang and Read, 1989), but inhibited rooting (Fig. 1). IBA, IAA, and NAA in the forcing solution enhanced rooting of the softwood cuttings. This response was typical of auxin-type responses found when such compounds are applied directly to cuttings. Results of the IAA, IBA, and NAA treatments were similar for all three growth regulators and therefore only the IAA results are presented in Table 1.

When GA_3 and IBA were included in the forcing solution sequentially, i.e., addition of IBA following inclusion of GA_3, the GA_3-induced inhibition was

counteracted and rooting was stimulated. We propose that this protocol can be used as a potential means to expedite macropropagation of woody species in the off-season. We have also initiated research to determine the utility of using forcing solutions as an efficient delivery method for root-enhancing chemicals and to examine the potential applications for propagating recalcitrant woody species.

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WEDNESDAY MORNING 2 DECEMBER 1992

The morning session was convened at 8:00 p.m. with Anna Knuttel serving as Moderator.

The following short papers by Albert Bremer, Michael Byers, Nancy Gillian, Ron Fox and Bill Molter, Jon Prickerill, Mark Richey, and Fred Bauer were part of a **Plant Propagation Problems and What We Have Learned** panel moderated by Dale Deppe.

Drought Stress on Scion Wood

Albert Bremer
Environment Improvement, 10100 E. Michigan Ave., Box 48, Parma, Michigan 49269

Generally our budwood is cut from local nursery stock blocks. However, during the summer of 1991 our nursery obtained its budwood from central Illinois which was in the midst of a drought. This created a number of unforeseen problems.

Rootstocks which were to be budded grew very well that summer in Michigan and averaged 3/8 inches in diameter. The small drought-stressed sticks received from Illinois were immediately chip budded. When the small scion wood buds from the drought-stressed stock block were conventionally grafted, cambial contact between the graft surfaces was insufficient or non-existent. To overcome this problem, scion buds were placed on the rootstock graft area at an angle to permit at least minimal cambial contact. The buds were then completely covered with poly tape.

After six weeks buds appeared healthy. However, another inspection in December showed more than half of the buds dead. An attempt to rebud the unsuccessful grafts was planned for the spring. This rebudding would prove to be another mistake.

Dormant budwood unaffected by drought, was cut in January and placed in cold storage for use in the spring. Two major problems occur with spring rebudding. Live bud eyes have their understock tops removed to force new growth. Budded understock with dead buds and existing tops are then chip budded on the opposite side of the rootstock. A narrow poly tie which exposes the bud eye to open sunlight is used so growth can occur. This process is very time consuming and requires skilled labor at a time when other tasks in the nursery are far more important.

The second problem with spring rebudding is that all trees in the same row do not require grow straits, limbing, and staking at the same time. There are two groups of plants at different stages of growth. Many trees lose their central leaders, for they are tied too late in the season. The final result is a large number of trees rejected at harvest time.

Propagation of *Cotinus coggygria* 'Velvet Cloak'

Michael L. Byers
Ridge Manor Nurseries, 7925 N. Ridge, Madison, Oh. 44057

Our first experience with propagating *Cotinus coggygria* 'Velvet Cloak' was in 1989. Cuttings were taken in late August, treated with 5,000 ppm IBA in talc, and stuck in a peat : perlite mix (1 : 1, v/v) with intermittent mist. Every cutting rotted within 14 days. In 1990 we collected cutting wood that was just completing a

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growth flush in early July and treated it the same as previously. Fifty-seven cuttings rooted out of 231 stuck. The cuttings that did not root had rotted at the base very shortly after being stuck. Realizing that excess water was detrimental, we stuck the next years crop in sand (#400 silica sand) to minimize moisture retention. There was a marked decrease in the amount of rotting, but very little rooting occurred. We believe the coarseness of the sand caused the cuttings to produce excessive callus, but no roots. In February 1991, we stuck hardwood cuttings taken from bareroot plants. They were stuck in 92 cell plug trays using a peat moss and styrofoam mix (1 : 1, v/v). Cuttings were treated with 2,500 ppm K-IBA solution and given 55°F forced-air bottom heat. The cuttings rooted 82% in eight weeks. Successful rooting was also achieved in June 1991 with softwood cuttings in a peat and styrofoam mix, 5,000 ppm IBA talc, but with only hand misting. In January 1992, we repeated our hardwood procedure with favorable results. We are confident that with proper attention to cutting wood maturity, rooting medium, and soil moisture, these systems will continue to work well for us.

Propagation Methods at Berthold Nursery

Nancy Gillian
Berthold Nursery, Woodstock, Illinois

I would like to share with you the hardwood and softwood propagation methods we use at Berthold Nursery which is located in Woodstock, Illinois, on approximately 400 acres.

We start our season with hardwoods, doing approximately 5 to 6 thousand cuttings. Cuttings are taken December through March when the outside temperature is above freezing. We propagate plants such as dogwood, privet, spirea, honeysuckle, and currant by this method.

Until a couple of years ago all our hardwoods were lined directly into the field after they were fully callused in our cooler. However, after returning from our 1989 I.P.P.S. meeting in Toronto Canada, I wanted to try a technique I saw being used at Canon Nursery. They were sticking their hardwoods into media in 5-gal cans, and keeping them in their container area. This idea appealed to me. I like this method because I can control their environment. I also have easier access in the spring and can keep an accurate check on rooting success. This allowed me to better schedule my softwood cutting propagation. When its time to line them out into the field these plants do not have to be harvested first. The planting crew can take the cans to the field at planting time, separate them there, use what they need, and return the unused plants to the container area for later planting.

My first attempt in a 8-gal container was fairly successful. However, because I put 100 cuttings per can the plants were to small. The second season I cut the number in half and that gave us fuller plants. This year was my third try and I liked what I saw. We had better than 80% take in most plants. However, because we are conservative, we still line some of all hardwood propagated plants into the field. As we become more confident of our container propagation method, we plan on eliminating direct field production all together.

Our primary propagation method is by softwood cuttings. We do about 100,000 cuttings per season. We begin softwood production in early May, as soon as I see that

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the plants in the stock blocks have flushed. I prefer to begin taking cuttings as soon as the wood is ready and want my cuttings to be no less than 6 to 10 in. long. We leave as much leaf area as possible. This usually means taking only the bottom one third of the leaves off. We then dip them into a hormone powder and stick directly into sand beds. I have found that I don't have as large a plant when I wait to long to take cuttings—timing is everything.

I start my softwood propagation with *Spiraea*, *Potentilla*, *Berberis*, and *Cotoneaster*. We do softwoods in both 1- and 2-year beds. The 1-year plants are stuck in hoop houses that are 24 × 50 ft. The 2-year cuttings are in beds in self-contained houses. After the first season with 2-year cuttings, we remove the plastic and hoops, and allow them to continue growing in the beds for another year. All our in-ground propagation beds are 4 ft × 50 ft × 8 in. and filled with #2 grade sand. The 2-year beds, however, have a compost mix below the sand to support expanded rooting and allow for easier harvesting. Both the 1- and 2-year beds run on the same water system. Misting is provided by floral mist nozzles spaced every 3 ft on 2-ft risers set on top of ½-inch PVC water lines. These nozzles cause almost a fogging effect and the humidity stays at approximately 85% to 90%. I keep these houses sealed shut at all times. Until last year both 1- and 2-year cuttings were spaced on 1 in. centers. We felt that the 2-year plants did not have appropriate spacing so we increased the spacing to 2 in. on center. This produced a much fuller plant with extra branching after the second year. Once rooting occurs we start the hardening off process by first opening the houses so the air can move through, next the plastic is removed and replaced with black shade cloth. Then I begin to cut the mist back until it is stopped and then we go to manual monitoring and watering. By this time we are approaching the middle of August. The first stuck *Spiraea* and *Potentilla* are now ready to be potted into quarts. We move through each house taking all the plants that are ready for potting. We leave the types that may not transplant well in the fall and those that need additional rooting time are allowed to remain in the bed until the following spring.

Many people question us as to why we stick into sand and then pot into quarts. Why the extra step? We feel this extra step is worth it because most of our fields are a heavy clay soil type. We have seen plants that were too small, such as 2 ¼ in. peat pot and grow plug size, struggle in such soil, and we have witnessed phenomenal losses with such small root systems. Our 1-quart plants are at least 10 in. tall and have a larger root system. This larger root system helps the plants become established in the field. These plants take off better in the field for us with a doubling or tripling in size during the first season. We also have another use for the quart container plants. Many times we move the plants up into larger containers for our sales yard. These quarts are large enough to move into 1- and 2-gal containers. This eliminates shifting two or three times to get a plant into a 5-gal can. As in the field, we see much greater vigor from these quarts. As winter comes on the houses are once again covered with plastic. We water everything and hope for a freeze. I do not seal my houses for the winter. Instead, I try to keep the cuttings frozen by venting through wing windows. I have found that our houses can be as warm as 60°F on a sunny calm day even if the temperature outside is only 20°F. I close the houses when the snow comes or the temperature drops into the lower teens or single digits during the night and reopen when the sun comes back and begins to warm the houses. Our overwintering losses have been greatly reduced since starting this procedure.

In conclusion, we know that the procedures outlined are more time consuming than other methods, but we feel the product produced is more successful. We additionally feel we have a much greater control over our products.

Freeze Damage on *Taxus* Cutting Wood

Edward R. Fox and Bill Molter
Home Nursery, Inc., P.O. Box 307, Edwardsville, Illinois 62025

Recently, we experienced a propagation problem at Home Nursery when freeze damaged *Taxus* cutting wood was used. Historically, we have always taken taxus cuttings from field grown plants rather than the container grown ones. In the fall of 1990, we switched and began taking our cuttings from container grown plants because harvesting was easier and quicker due to closer plant spacing. In addition, because the plants were in covered polyhouses, the cuttings could be taken during bad weather.

Last fall we planned to compare the performance of cutting wood taken from containers with that from field plants. We began with cuttings from field plants and then proceeded to take them from the containers. However, in early November we experienced several days of record to near record lows. A record low of 8°F on November eighth was 7°F below the previous record on that day. At the time there were no visible signs of damage to the taxus and we were more concerned about the fate of some of our container grown broadleaved plants.

Problems began to appear in late December with the field cuttings in the propagation beds. Some cuttings were showing basal rot with many more exhibiting necrotic spots up and down the stems. Needle drop was also occurring. For a while we thought we might lose all of the field cuttings. As it turned out our losses from the field cuttings were 16% versus 4% from the cuttings taken from the protected container yews. The field cuttings also exhibited more uneven bud break this last spring. The following spring the longer shoots left on field plants die back to the body of the plant.

This near miss, so to speak, just served to reinforce something that we already knew—beware if anything changes, such as the occurrence of a freeze of this magnitude. In hindsight we should have made a conscious decision as to whether or not to use the wood from the field grown plants before we ever began to take the cuttings.

Overwintering Rooted Cuttings of *Viburnum carlesii*

Jon D. Pickerill
The Wilson Nursery Group, 43W967 State Route 72, Hampshire, Illinois 60140

Viburnum carlesii, and its hybrids and cultivars, have typically been a high-demand and short-supply item at Wilson Nurseries. As a propagator, I'm sure I'm not alone in having been frustrated countless times by this plant. Numerous mistakes and many dead plants later, I have learned a few things about these viburnums which I would like to share.

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At first, we tried in vain to make *V. carlesii* fit into a propagation schedule which we successfully used for most of the plants that we propagate. Softwood cuttings were taken in mid-June from plants in production. We made and bundled the cuttings in the field and stored them at 45°F prior to sticking. The cuttings were treated with 10,000 ppm K-IBA and stuck in sand in a 30 ft × 168 ft quonset house and misted with a Growing Systems mist boom.

By August, 90% or better were rooted. The plants were allowed to go dormant and were lifted from the sand beds in November. The dormant rooted cuttings were then wrapped in plastic and stored in a freezer at 28°F.

Coming out of the freezer in the spring, the roots and tops of the *V. carlesii* rooted cuttings looked alive and healthy. The plants were lined out in the field in April in 3-ft beds. The beds were irrigated immediately after planting and periodically thereafter. The results were less than satisfactory—30% stands for *V. carlesii*.

Through a couple more years of trial and error, we finally have come up with a method which, we believe, will consistently give us superior results. Cuttings are taken in June with the same treatment prior to sticking. However, this time the cuttings are direct stuck in 3-in. pots in a peat-bark mix. Instead of an unheated quonset, they are rooted in a 30 ft × 200 ft, double-poly, heated quonset house. As before, a Growing System boom is used to mist the cuttings, however, one must be much more careful with the water because the peat-bark mix tends to waterlog.

After the cuttings have rooted, they are grown on and allowed to go dormant in the fall. They are then left in place and maintained throughout the winter at 28°F. The following spring the plants are allowed to break bud, grow, and are cut back once prior to planting in the field in May.

I repeat, the returns we have experienced have been excellent. Furthermore, I believe these results can be duplicated year after year.

Feeding Cuttings to a Slow Death

Mark L. Richey
Spring Meadow Nursery, Inc., Grand Haven, Michigan 49417

Everyone has experienced those mysterious overwintering deaths that occur in seemingly healthy stands of rooted cuttings. It's easy to rationalize what caused the problem without ever really rooting out the source so as to prevent it from happening again. We faced that situation this year at Spring Meadow Nursery. Cuttings flushed and then the new shoots collapsed within a very short time. Lab reports said that no pathogens were present, but there was considerable cambium damage. The question we had to answer was "how?" or if it happened again "how would the nursery survive economically?"

Certain patterns showed up with the problem. Plants that had been stuck or potted in the last half of the year showed the most loss, but only the ones in bark media. Cuttings stuck in perlite overwintered fine, for example *Euonymus alatus* 'Compactus' were rooted in perlite and then upgraded to 2¼-in. pots in mid–September using a pine bark medium. Overwinter losses with the 2¼-in. pots were about 50%, but the ones that remained in the plugs had virtually no winter losses. Other examples are *Spiraea japonica* 'Little Princess' and *Viburnum plicatum* f. *tomentosum* 'Mariesii' that were direct rooted in a 2¼-in. pot, then shifted to a 4-in.

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Feeding Cuttings to a Slow Death

Mark L. Richey
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Everyone has experienced those mysterious overwintering deaths that occur in seemingly healthy stands of rooted cuttings. It's easy to rationalize what caused the problem without ever really rooting out the source so as to prevent it from happening again. We faced that situation this year at Spring Meadow Nursery. Cuttings flushed and then the new shoots collapsed within a very short time. Lab reports said that no pathogens were present, but there was considerable cambium damage. The question we had to answer was "how?" or if it happened again "how would the nursery survive economically?"

Certain patterns showed up with the problem. Plants that had been stuck or potted in the last half of the year showed the most loss, but only the ones in bark media. Cuttings stuck in perlite overwintered fine, for example *Euonymus alatus* 'Compactus' were rooted in perlite and then upgraded to 2¼-in. pots in mid–September using a pine bark medium. Overwinter losses with the 2¼-in. pots were about 50%, but the ones that remained in the plugs had virtually no winter losses. Other examples are *Spiraea japonica* 'Little Princess' and *Viburnum plicatum* f. *tomentosum* 'Mariesii' that were direct rooted in a 2¼-in. pot, then shifted to a 4-in.

pot in late August. By spring a large percentage of them were dead. We formulated a couple of theories to explain the losses, but every time the focus came to fertilizer.

We had been incorporating a slow-release fertilizer with a 9-month release in all of our media. Sometime in late spring, our supplier visited the nursery with the technical rep of the fertilizer manufacturer. They analyzed our usage and then recommended a shorter, 4- to 5-month release fertilizer. It was after many discussions that we switched over to what was recommended. The plants grew well and seemed to go dormant as expected. We overwintered the crop in minimum-heated, double-poly greenhouses and then turned the heat up when they started to grow in early March. The plants had looked good all winter. Then the problem described earlier showed up. One of the discussions I had with the plant pathologist at Michigan State University clicked an idea I had never thought of before. A deciduous plant could drop it's leaves in the fall and still not go dormant. I pursued that line of thought to find out how the cambium damage occurred. Our minimum temperatures could have been set too low if internally the plant was still active, but why were they still active? We invited the representative from the fertilizer company to help solve the problem. He noticed the prills of the fertilizer were spent when there should have been some fertilizer left to get the plants going in the spring. Since we didn't keep any soil temperature data, we couldn't determine if the fertilizer had failed to perform as it was recommended. However, we did draw some conclusions.

First, the shorter-release fertilizer starts releasing quicker than we had experienced in the past. We were told it would take seven days with an average soil temperature of 50°F to start releasing. This either is false information or the release didn't shut down as predicted in the fall. This year, we didn't incorporate any slow-release fertilizer after July 1 so as to make sure it was gone by the end of October.

Second, we have grouped our plants into seven categories by growing characteristics. We hope to minimize the growing environment as a factor in overwintering deaths.

And third, we are "shading" a few houses with a sheet of white poly over the double clear sheets for the winter. We want to know how much we can reduce the variation in day/night temperature. In the spring, the white poly will be removed so the plants won't be held back.

Too many times I've heard excuses for winter losses. This is one practical lesson for which we paid dearly at Spring Meadow.

Mist Nozzles that Work for Us

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We found it necessary to close out production of all junipers and drastically increase our summer softwood liner production because of changes in our liner production business in past years. In the past we only kept enough propagation equipment on hand to meet our production schedule. However, with the increase in summer production we found ourselves short of mist nozzles. In the past, we had our nozzles custom assembled and modified from parts available through a local source. However, the gentleman who did this procedure died, and we have been unable to locate a machine shop that was willing to do this identical modification.

Table 1. Agrofim State-Flo Mister nozzle, Model SF-32, before and after modification.

	Standard factory	After modification
Orifice (in.)	0.032	0.625
REC PSI	45	120
Discharge (GPH)	8.0	40.0
Coverage discharge (in.)	48	50

After finding that we had $5.00 invested in a nozzle that was not as satisfactory as the one that we were using, we started to check horticulture supply houses for an alternative nozzle. Following several years of searching and testing, we found a nozzle, the State-Flo Mister by Agrofim at a cost of fifty cents each, that could be made compatible with our existing propagation equipment. The nozzle had to be modified because of an uneven, coarse-spray pattern, sometimes with no spray pattern at all, when received from the company. To correct the spray pattern, we bored the nozzle head with a one-sixteenth inch standard drill bit. Table 1 shows a comparison of the nozzle before and after modification. By placing the Agrofim State-Flo Mister nozzle in a one-fourth by one-eighth galvanized bushing, it would fit into our standard riser. This riser is constructed of a one-fourth galvanized hex cap brazed to a number eight wire, 20 in. in length with a 3/16 in. hole being punched in the hex cap.

In vitro Root Suckering of Aspen (*Populus tremuloides*)

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The development of an in vitro protocol for the growth of roots and the subsequent production of microshoots from the suckering of the roots of two clones of *Populus tremuloides* (quaking aspen) was studied. Root growth was greatest with attached shoot tips. Adventitious bud initiation from root explants was greatest using Murashige and Skoog medium, supplemented with 3% sucrose and 1.0 mg/liter thidiazuron. The addition of 0.01 mg/liter NAA did not enhance adventitious bud initiation. Shoot development and elongation after adventitious bud initiation was achieved by growing the adventitious bud clusters on medium supplemented with 0.1 mg/liter BA for 8 weeks (2 cycles). Rooting and acclimation of the root-derived shoots was the same as traditional shoot-tip-derived shoots.

INTRODUCTION

Because of additional applications, the forest industry demand for aspen has increased during the past few years. At one time it was used primarily for pulp and paper. Now it is in demand for waferboard, oriented strand board and packing crates (Adams and Gephart, 1989; Prosek, 1988).

To meet these demands and to keep abreast with anticipated increases, clonal forestry is now being considered in the United States. Aspen does not propagate well by cuttings, so historically, foresters have planted non-selected seedling trees. The primary restriction to large-scale field planting of cloned, superior aspen is the shortage of readily available, affordable propagules. Tissue culture of aspen using the traditional shoot-tip method can be accomplished, but it is prohibitively expensive. Foresters will only plant superior material if the plantlet price is near the price of seedling produced material (currently $150-250 per thousand).

Root-sucker propagation is most often used to clonally propagate aspen. Roots are dug in the spring, washed, fungicide treated, and placed in sand. After 10+ days, shoots emerge from the roots which are removed and rooted as cuttings. This method works, but it is limited by the amount of available root material and appears to be only seasonally successful.

This paper discusses our investigations of the use of this natural root-suckering phenomenon in a micropropagation program. If we could grow isolated roots in vitro indefinitely, and regenerate microshoots on demand from those roots, we could micropropagate aspens without seasonal restrictions or the availability of root material. This paper reports the biological feasibility of this technique.

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However, further research is still underway to optimize the methodology and yield. After optimization, cost evaluations will be conducted.

MATERIALS AND METHODS

In Vitro Shoot-Tip Cultures. *Populus tremuloides* clones 3 and 17A were selected as test subjects because they are considered superior genotypes with potential commercial value. Clone 3 is considered to be "easy" and clone 17A "difficult" to propagate using standard shoot-tip tissue culture procedures. Actively growing, greenhouse-derived, shoot-tip cultures of the two clones were established using standard commercial protocol. Throughout this study, we used Murashige and Skoog (MS) Medium supplemented with 3% sucrose, with the pH adjusted to 5.7. Proliferation-stage medium was supplemented with 0.5 mg/l benzyladenine (BA). Microshoot-elongation medium was supplemented with 0.1 mg/l BA. Individual shoots were then selected and used in subsequent root growth and for vitro root-suckering studies.

Root Growth Studies. To initiate adventitious root growth, individual shoots of clone 3 were transferred to medium without growth hormones. After approximately 10 days when the roots reached 10 mm in length, the root/shoot unit was subjected to treatments based on preliminary results which indicated the attached shoot and/or darkness may be important for continued root growth. To test these possibilities, half of the shoots were trimmed to 2 mm before all were placed vertically onto a filter paper support in a Magenta GA7 vessel containing liquid medium supplemented with 1.0 nM naphthalene acetic acid (NAA). Half of each group (trimmed or non-trimmed) was placed in the dark and the other half remained in the light. Ten explants per treatment were used and root growth was measured every 3 days for 30 days.

In Vitro Root Suckering. Roots from microshoots were harvested and placed onto adventitious-bud-initiation medium supplemented with BA at 0.0, 0.5, 1.0, and 1.5 mg/l, or thidiazuron (TDZ) at 0.0 0.01, 0.1, and 1.0 mg/l. Both BA and TDZ were tested with or without 0.01 mg/liter NAA. Root-explant length was 0.5, 1.0, 2.0, and 4.0 cm. Explants remained on the initiation medium for 4 weeks followed by 8 weeks (2 cycles) on shoot-development medium containing 0.1 mg/l BA. Ten explants were tested per treatment and each treatment was replicated.

Rooting and Acclimation. Microshoots from root explants were harvested, rooted, and acclimated using standard ex vitro protocol. The microshoots were stuck into a peat : perlite : vermiculite mix (1 : 1 : 1, v/v/v) in 288 plug trays, covered with a Jiffy Dome, and placed under 16 h light period supplied by CW fluorescent lamps. Acclimation was accomplished by replacing the solid Jiffy Dome after 3 weeks with a ventilated Jiffy Dome.

RESULTS

Root Growth. Root growth was greatest when the root remained attached to the stem, whether or not the explant received light. The poorest root growth was from roots grown in the light without attached stems (Fig. 1).

Table 1. Influences of TDZ and NAA on the mean number of adventitious bud clusters and microshoots derived from *Populus tremuloides* root explants.

Initiation treatment	Mean number of adventitious bud clusters		Mean number of microshoots	
	Clone 3	Clone 17A	Clone 3	Clone 17A
0.01 TDZ	0.18	0.10	0.20	0.04
0.01 TDZ + NAA	0.11	0.13	0.06	0.04
0.1 TDZ	0.19	0.38	0.19	0.12
0.1 TDZ + NAA	0.19	3.31	0.06	0.16
1.0 TDZ	0.30	0.39	0.06	0.82
1.0 TDZ + NAA	0.26	0.31	0.12	0.42

Note: TDZ concentration is mg/l.
NAA = 0.01 mg/l.

In Vitro Root Suckering. Data on root suckering (adventitious bud initiation and microshoot development) were extremely variable and were not suitable for statistical analysis. To assess the data for trends that would assist in further study the data were pooled whenever possible and are presented in that format in this report.

No adventitious buds formed on explants on control medium or medium containing BA. Only explants grown on medium supplemented with TDZ produced adventitious buds. There was also no effect of explant length on whether or not it had the capacity to form adventitious buds. Adventitious-bud formation and microshoot development for both clones is shown in Table 1. Root explants of both clones 3 and 17A produced the greatest number of adventitious bud clusters when treated with 1.0 mg/l TDZ and was not enhanced by the addition of NAA.

Clone 3 microshoot development after 8 weeks on developmental medium (0.1 mg/l BA) was best if adventitious buds were initiated on 0.01 or 0.1 mg/liter TDZ (Table 2). Clone 17A microshoot development was best when adventitious bud were initiated on 1.0 mg/l TDZ.

Rooting and Acclimation. Rooting and acclimation of the microshoots was 92% for clone 3 and 96% for clone 17A.

DISCUSSI0N

The poor growth of roots without attached shoots may be due to the lack of a shoot-produced substance.

The initiation treatment that resulted in the greatest number of adventitious-bud clusters did not result in the greatest number of microshoots for clone 3, but did result in the most microshoots for clone 17A. The lower number of microshoots that developed from clone 3 explants may be due to a carryover inhibition by the high

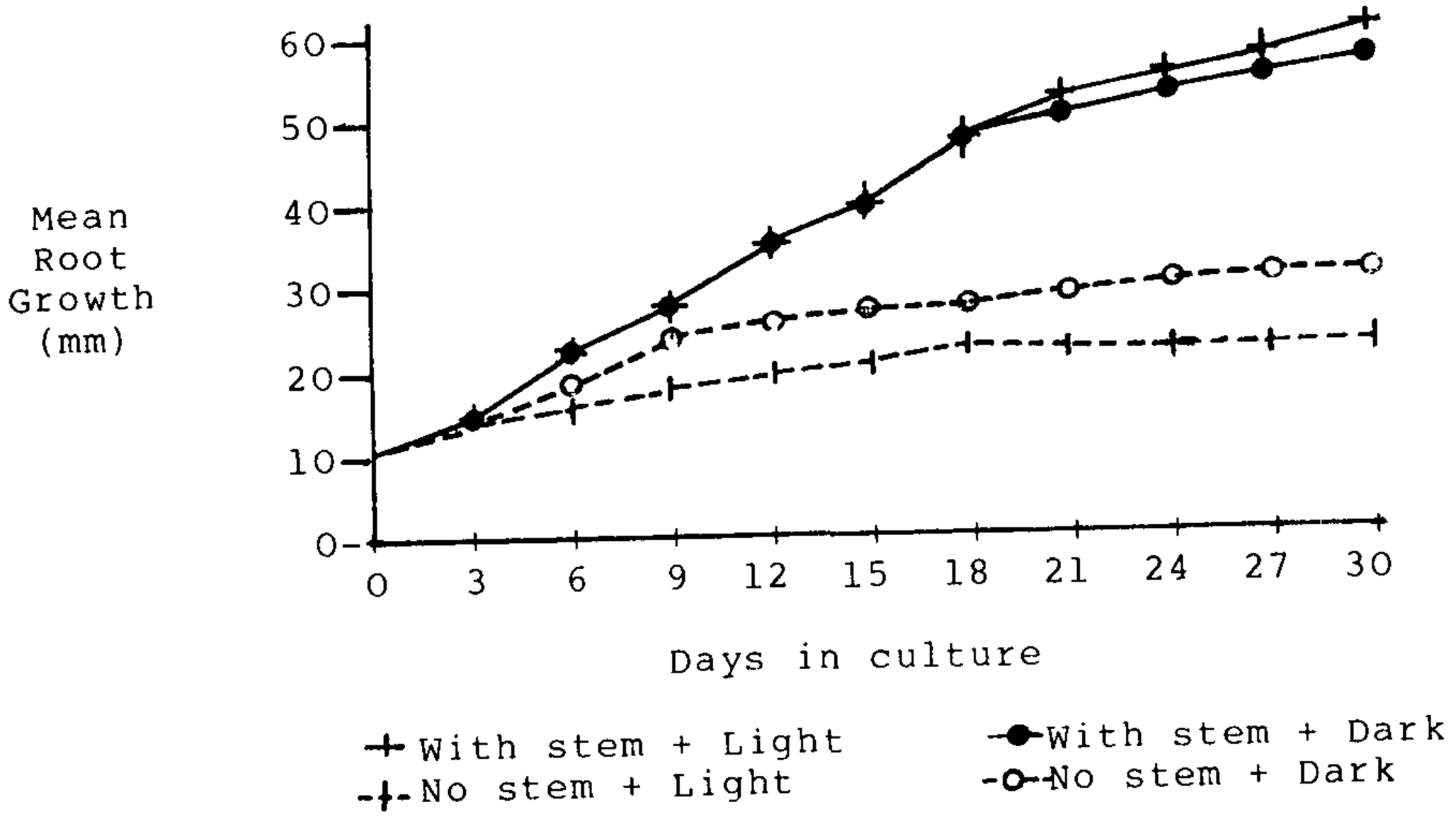

Figure 1. *In vitro* root growth of *Populus tremuloides* Clone 3.

level of TDZ or by a competition among the numerous adventitious buds. The addition of NAA did not increase the number of microshoots that formed on the root explants. This is contrary to adventitious-shoot development when leaf-segment explants are used in hybrid poplar (Lee-Stadelmann et al, 1989).

Rooting and acclimation were the same as for the traditional shoot-tip micropropagation technique.

The initiation of adventitious buds from root explants and the subsequent microshoot development, although variable at this time, appears to be quite feasible. This *in vitro* method is not limited by a shortfall of field harvested roots or by seasonal variations of in situ root suckering.

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Seedlings Versus Tissue-Cultured *Kalmia latifolia*: The Case of the Missing Burl

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Basal burls, also known as lignotubers, are defined as aggregates of developmentally suppressed shoot buds which form at the base of the primary stem of seedlings as part of their normal ontogeny. Basal burls are commonly found in plants native to Mediterranean-type climates where fire is an important part of the local ecology. Following traumatic injury to the main stem, basal burls will sprout out vigorously to produce new shoots. In *Kalmia latifolia* (mountain laurel), the tendency to form basal burls seems to be greater in seedlings than in tissue-cultured plants, an observation that has important implications for the field of plant propagation.

INTRODUCTION AND DEFINITIONS

The subject of burl development in woody plants has never received the attention it deserves in either the horticultural or the botanical literature. The intent of this paper is to remedy the situation by: (1) providing a general overview of what is known about burl development; (2) examining the details of burl development in *Kalmia latifolia*, the mountain laurel (Ericaceae); and (3) exploring the implications of burl development for the field of plant propagation.

The existence of swollen, underground "root crowns" has been documented in a variety of ericaceous genera, including *Arctostaphylos* and *Arbutus* in the chaparral zone in California and *Erica* in the western Mediterranean region (Mesléard and Lepart, 1989). In both of these groups, burls, which are covered with "adventitious" buds, form at the base of plants. These buds remain dormant until some traumatic disturbance—particularly fire—damages or kills the trunk, at which point they sprout to produce new shoots. Garland and Marion define an ericaceous burl as:

> ". . . an aggregation of short branchlets fused into a complex, patterned mass of wood. At its surface the branchlets are terminated by dormant buds, which are capable of sprouting when the main trunk is destroyed or the plant undergoes fire or other injury."

One key concept that should be added to this definition is that burl formation is part of the normal ontogeny of the plant and not simply "induced" by environmental factors. Indeed, the presence or absence of a burl has been used as a valid taxonomic trait for distinguishing species in the genus *Arctostaphylos* in California (Jepson, 1916; Weislander and Schreiber, 1939; Wells, 1969).

While burls typically form at or below the soil surface, they can also develop on above ground portions of the trunk, particularly on older plants. I suggest the term basal burl for those structures that occur underground (Fig. 1), and aerial burl for those that occur on the trunk above ground. Woody plants which are capable of

vegetative reproduction from basal burls, or lignotubers as they are also called, are most commonly found in Mediterranean-type climates where fire is an important part of the ecology. Besides being formed on ericaceous plants, burls have also been reported in a variety of non-ericaceous genera including,*Eucalyptus* (Myrtaceae) in Australia (Carr et al., 1984), *Leucospermum* (Proteaceae) in South Africa, and *Ceanothus* (Rhamnaceae), and*Adenostoma* (Rosaceae) in California (James, 1984). Several gymnosperms are also known to form both basal and aerial burls, including *Ginkgo biloba* (Ginkgoaceae) (Del Tredici, 1992) and *Sequoia sempervirens* (Taxodiaceae) (Olson et al., 1990), both of which are considered fire-adapted species.

The earliest stages of basal burl development have been carefully studied in only *Eucalyptus* (Carr et al., 1984) and *Ginkgo* (Del Tredici, 1992). In both cases, burl formation starts with the proliferation of buds located in the axils of the cotyledons of young seedlings. In *Ginkgo* burl development is generally restricted to the cotyledonary node, while in *Eucalyptus*, nodes immediately above the cotyledons also become involved in burl development.

The view that basal burl formation is part of the normal ontogeny of those species in which they occur has not been widely accepted. Typically burls, both basal and aerial, are considered to be a "pathological" condition induced by some unknown vector (Haller, 1986). This misconception has arisen because of the failure to distinguish those burls that are induced by pathogenic agents (such as crown gall) from those that are associated with "normal" developmental processes. The situation is further complicated by the fact that many of the species that form basal burls also form aerial burls in response to severe crown or root damage (Del Tredici, 1992). At the physiological level, the distinction between basal and aerial burls is one of degree rather than substance, the former being triggered by endogenous developmental processes, the latter by exogenous environmental events.

The literature documenting burl formation in *Kalmia latifolia* consists of a single article by Barrett (1941) describing how burls were collected from wild plants for the purpose of manufacturing smoking pipe bowls, a use to which the burls of other Ericaceous plants, including *Erica arborea* (the true source of briar pipes) have traditionally been put (Fairchild, 1938; Garland and Marion, 1960). Unfortunately Barrett does not document the developmental morphology of burls in young plants or the ecological factors that determine why some plants have large burls and others do not. In the authoritative work on cultivated *Kalmia* (Jaynes, 1988) there is no specific mention of burls, although Figure 2-10 of the book shows a wild plant in Georgia with a large, exposed basal burl. In an unpublished PhD thesis on the ecology of mountain laurel by Kurmes (1961), basal burls are documented as the source of new stems following fire, logging, and hurricane damage.

Kalmia burls are still of economic importance in the mountains of North Carolina, where the plant is collected from the wild for horticultural purposes. The collecting process involves cutting back old plants to near ground level in the fall or winter, thereby inducing them to sprout out from basal burls the following spring. Collectors return the next year to dig up these laurel "plates," as they are called, which are then lined out in a nursery before being sold.

MATERIALS AND METHODS

In order to examine the early stages of burl development in mountain laurel, 50 seedlings of *K. latifolia* of various ages were collected from the wild in Connecticut

(along Interstate Highway 84) and at the Harvard Forest in Petersham, Massachusetts. Preliminary observations on the early stages of burl development were made on these plants using a 40× Wild dissecting microscope.

Based on the general observation that burl development seems to originate at the cotyledonary node, a preliminary study was undertaken to examine the question: Do *Kalmia* plants propagated vegetatively from rooted cuttings or tissue culture—and hence lacking the cotyledonary node—show the same tendency to form burls as seedlings do? To test this hypothesis, 4-year-old seedlings and 7-year-old tissue-cultured *Kalmia* plants (an unnamed cultivar) that had been raised under nursery conditions in Hamden, Connecticut, were compared with one another in terms of the extent of basal burl development. This was done by removing the fleshy, outer cortex from the base of the stem. Once the cortex was peeled away, it was relatively easy to count the numbers of clusters of xylem bud traces on the basal portion of the stem using a dissecting microscope.

RESULTS

Preliminary observations on wild-collected seedlings indicate that the first stages of burl development in *Kalmia* become clearly visible with the aid of a dissecting microscope only after the plants are at least two years old. At this stage, all of the axillary buds that are located on the stem segment produced during the first year of growth undergo proliferation to form discrete swellings that protrude out from the stem by the end of their second season of growth. Typically this process involves not only the cotyledonary nodes, but also anywhere from 3 to 8 nodes above the cotyledons. On most of the seedlings, which ranged in age from 1 to 6 years old, the swollen axillary bud clusters remained distinct from one another; on a few of the older plants, however, the basal bud clusters coalesced to form a distinct burl. On seedlings that had experienced severe trauma and were difficult to age, burl development was extensive, and axillary buds produced during the second or third year of growth were involved in burl formation (Fig. 2).

Table 1. Basal burl development in seedlings versus tissue cultured plants of *Kalmia latifolia* raised in a common nursery.

Plant type	Plants number	Mean diameter of basal burls ± s.d. (cm)	Mean bud clusters on basal burls ± s.d.
7-year-old tissue-cultured	7	2.36 ± 0.65	6.6 ± 3.9
4-year-old seedlings	8	1.30 ± 0.23	19.1 ± 3.2

The measurements comparing the nursery-raised seedlings and tissue cultured plants are summarized in Table 1 and illustrated in Figure 3. The most striking finding is that there were nearly three times as many proliferating bud clusters on

Figure 1. A large basal burl on *Kalmia latifolia* growing at the Highstead Arboretum in Redding, Connecticut. Note that in addition to the young sprouts, the burl is covered with numerous suppressed buds.

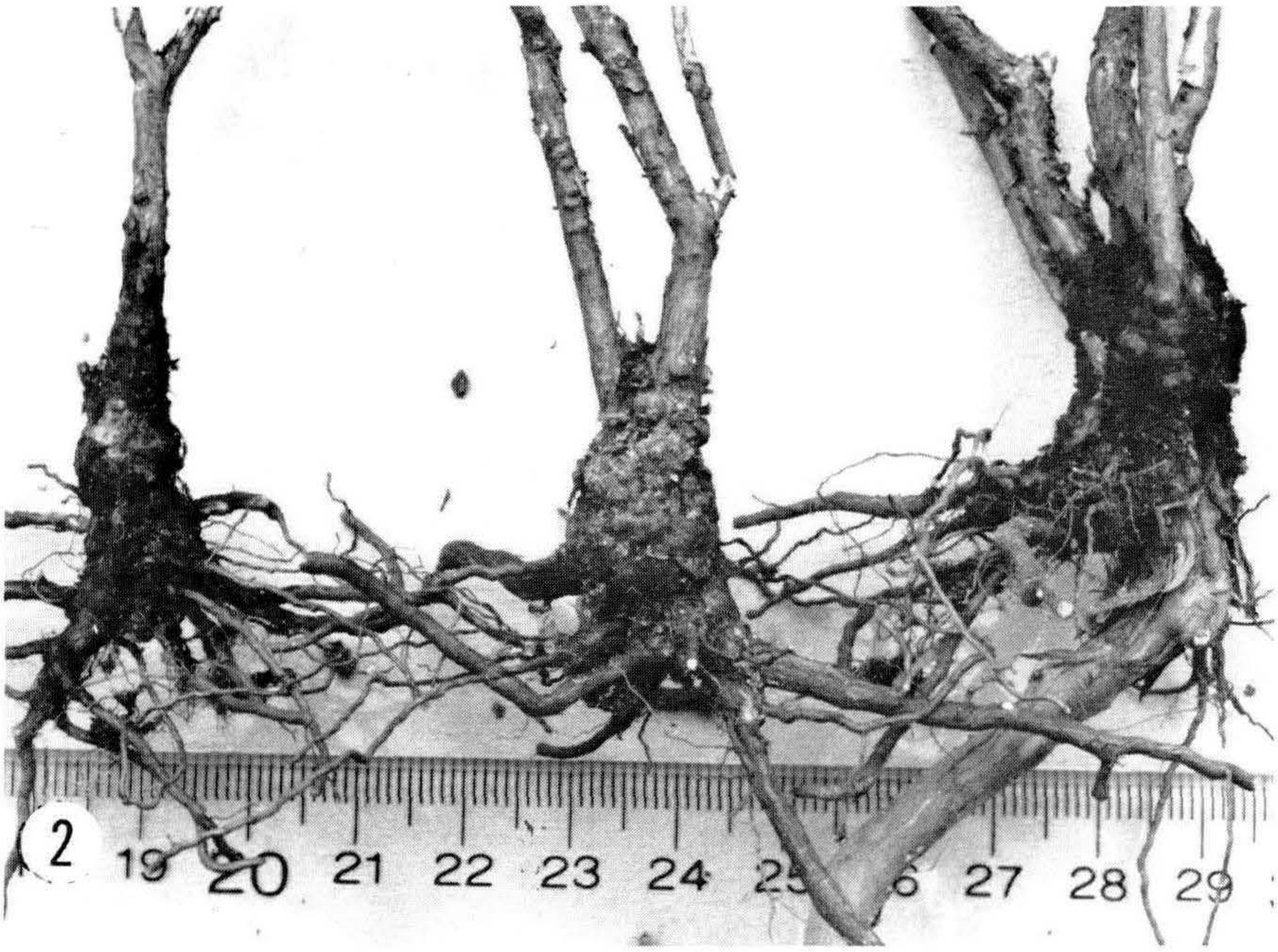

Figure 2. Young plants of*Kalmia latifolia* collected from the wild along Interstate highway 84 in Connecticut. Note the extensive basal burl development. Scale is in centimeters.

the basal portion of the stems of seedlings than on the stems of the tissue-cultured plants, this despite the fact that the seedlings were only slightly more than half as old and half as large as the tissue-cultured plants. This observation, which must be considered strictly preliminary, suggests that the ability to form basal burls is much greater in seedlings than in tissue-cultured plants. Whether this difference is due to the absence of the cotyledonary node has not yet been determined, but, at present, it is the most plausible explanation. A more thorough investigation of role of the cotyledonary node in basal burl formation is currently under investigation by the author.

DISCUSSION

As a working hypothesis, I would like to propose that the physiological processes that result in burl formation in *K. latifolia* are initiated at the cotyledonary node. Lacking the cotyledonary node as an organizing center, vegetatively propagated plants ought to show a diminished tendency to form burls. Other nodes located at the base of the stem of vegetatively propagated plants will form discrete clusters of embedded buds, but I suggest that these will not coalesce into the distinct basal burl which is typical of plants raised from seed. The implications of this are that in comparison to seedlings, vegetatively propagated plants (either tissue-cultured or rooted cuttings) ought to show a reduced ability to sprout following traumatic injury. The confirmation of this theory awaits further experimentation.

There can be no doubt that burls play an important role in the life cycles of those species in which they occur, and that a knowledge of the ecology, morphology, and

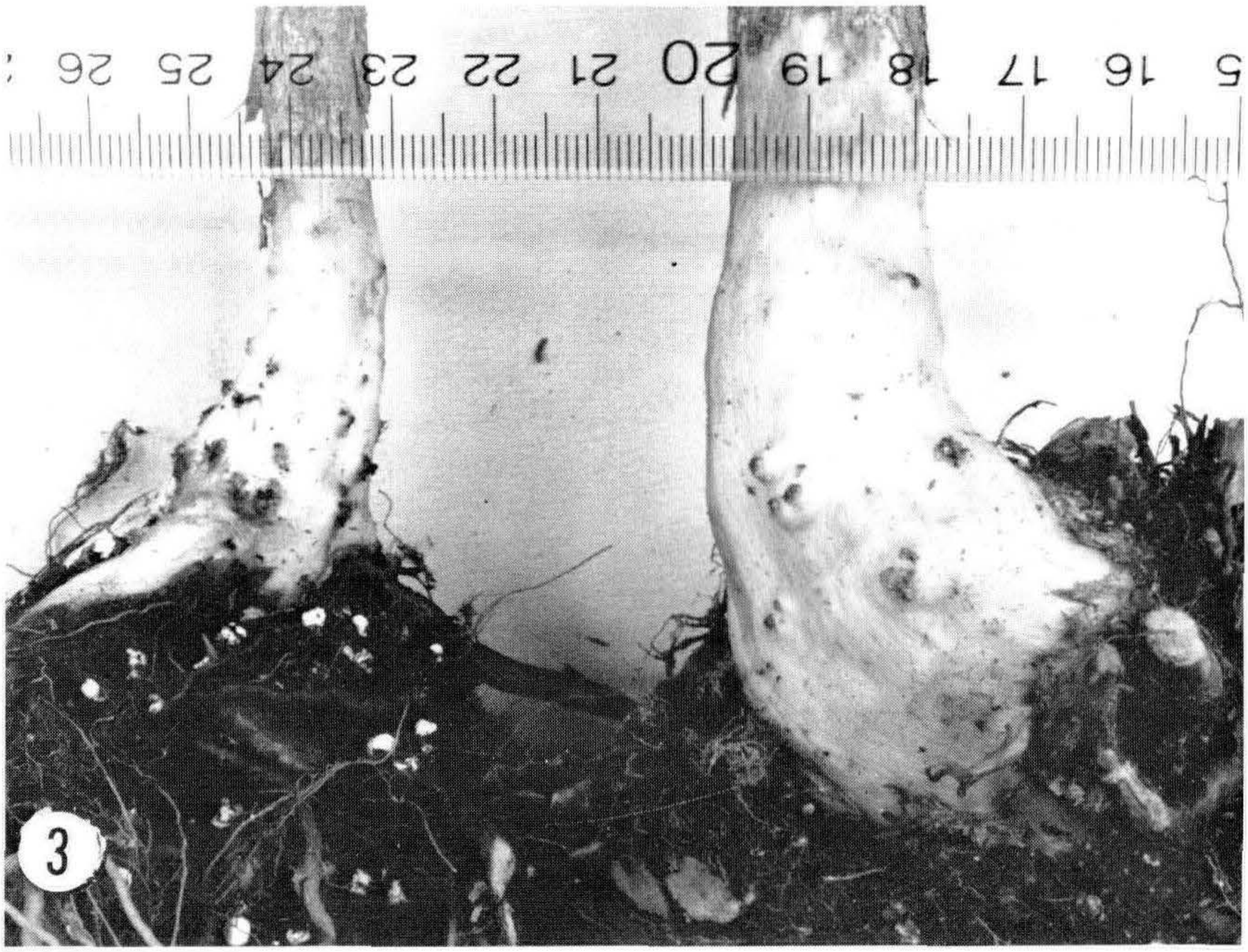

Figure 3. On the left is 4-year-old *Kalmia latifolia* seedling that has been decorticated to show the extent of basal burl development; on the right a 7-year-old tissue cultured plant. The seedling has 19 suppressed bud clusters in its basal region while the tissue cultured plant has only 9 suppressed bud clusters. Scale is in centimeters.

physiology of burl development might help explain the behavior of these species under cultivation. For example, the shoots produced by burls are considered physiologically "juvenile" in comparison to those produced by "mature" branches, and, consequently, they are usually much easier to root. In fact, many of the tree species that are successfully propagated by the traditional technique of "stooling" are burl formers in their native habitat. Another example of a situation where the process of burl formation may be relevant to propagation is in the phenomenon of "tissue proliferation," that has been reported to be a serious problem in tissue-cultured *Rhododendron* (LaMondia et al., 1992). It has been suggested that this unusual pattern of development is either (1) an artifact of the tissue-culture process itself; or (2) caused by an external pathogen. It seems to this author, however, that tissue proliferation could simply be a case of uncontrolled burl development that has been stimulated by the hormonal conditions that prevailed during the process of tissue culture propagation. Be that as it may, it seems likely that a clear understanding of the process of burl development as it occurs in nature might shed light on the behavior of *Rhododendron* microcuttings in tissue culture.

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Clonal Propagation of Biofuel Trees with Emphasis on Silver Maple

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There is a potentially great market for propagules to be used to establish woody biofuel plantations. Propagators and the nursery industry should be poised to profit from this market.

IMPORTANCE OF BIOFUEL CROPS

In the next 20 years there may be a new and expanding market for the nursery industry—the area of biofuels. Biofuels are trees and grasses that are grown for use as fuels or energy feedstocks (Wright et al., 1989). The primary grass being researched for biofuel production is switchgrass (*Panicum virgatum*). It is being grown as an agronomic crop and probably will not have much direct impact on the nursery industry. Among the woody species being studied for use as biofuels are: hybrid and pure species cottonwoods and poplars (*Populus* spp.), black locust (*Robinia pseudoacacia*), eucalyptus (*Eucalyptus* spp.), sweet gum (*Liquidambar styraciflua*), sycamore (*Platanus occidentalis*), and silver maple (*Acer saccharinum*). These woody biofuels are being grown and studied under short rotation conditions. This means that the closely spaced crops generally will be harvested within 10 years of planting. Most woody species have been selected because of their rapid juvenile growth rates and their ability to sprout from stumps (coppice), thus growers will not have to replant after each harvest, but can allow the coppice growth to be the subsequent crop. Yields are expected to exceed 11.2 metric bone dry tons per hectare per year (5 bone dry tons per acre per year). The United States Department of Energy, through the Biofuels Feedstock Development Program administered by Martin Marietta Energy Systems, Inc. has sponsored most of this research in the U.S. Sale of propagules of these woody species may prove profitable to the nursery industry as biofuel plantations increase in number and area planted.

The potential for biofuels is tremendous. Energy usage on a nationwide or worldwide basis is often measured in quadrillion BTU (Quads, 1 quad = 10^{15} = 1,000,000,000,000,000 BTU, 1 BTU = the amount of heat required to raise the

temperature of 1 pound of water 1°F). It is estimated that by 1995 the United States will use 87.9 quads of energy, 6.2 of these Quads will be from renewable resources (biofuels, including ethanol from corn, and hydroelectric power, etc.) (U.S.D.O.E., 1988). Biofuels may be burned directly, or used as feedstocks for the production of alcohol or gaseous fuels. Liquid and gaseous fuels (such as methane or natural gas) are easier to use than wood itself in industries such as transportation.

When fuels are burned they produce greenhouse gasses, especially CO_2. Unlike fossil fuels, the burning of biofuels is considered to be, at worst, CO_2 neutral, because the carbon dioxide that is being returned to the atmosphere was removed only recently when the plants were growing. At least over the short run, because trees store carbon in their roots and portions not harvested, they actually remove more CO_2 than they return to the atmosphere when burned. Another reason that there is increased interest in biofuel production is that it could reduce the dependence of many countries on imported fuel.

Woody biofuels are produced through "short rotation forestry," a technique more closely related to horticultural nursery production than to traditional forestry. Therefore the expertise of trained and experienced nursery personnel may prove invaluable as this technology advances.

As of December 1992, there were more than 22,455 hectares (55,500 acres) of hardwoods planted in commercial plantations under short rotation conditions in the United States. This area is much larger on a worldwide scale. Some people have estimated that production of biofuel crops could increase to as many as 20.2 million hectares (50 million acres) in the U.S. by the year 2010. There will be a large number of jobs created by this industry, involving both growers and users of biofuel crops. Members of the International Plant Propagators' Society should be aware of this market and industry members may apply their skills to facilitating the propagation and growing of these crops.

PROPAGATION OF WOODY BIOFUEL CROPS

To maximize crop uniformity, woody biofuels will likely be propagated vegetatively. Elite germplasm with rapid growth rates and resistance to pests and diseases will be most desirable to biofuel growers. This germplasm will likely be patented, and propagators will need to calculate the costs of royalties into their cost of production. Because of the high risk of planting large monocultures, biofuel growers should mix clones in their plantations or plant relatively small areas in a patchwork quilt design using several different clones. This quilt-like pattern facilitates harvesting, since clones will vary in growth rate. Propagators must therefore be willing to provide a variety of clones to biofuel growers.

Direct Field Rooting. Hybrid cottonwoods, poplars, sycamore, and willows are often planted directly in the plantation as nonrooted hardwood cuttings (Meridian Corporation, ca. 1986). This is attractive to biofuel growers because of the low expense compared to transplanting rooted cuttings. However, to be successful, cuttings must root in high percentages.

With easy-to-root species, propagators will only make a large profit if they produce and sell a sufficiently large number of cuttings. Future demand for woody biofuel species should be high if the propagator can provide excellent clonal material. The propagator will need to establish cutting blocks and produce sufficient numbers of

high quality, disease-free cuttings. Using hybrid poplar (*Populus* × *canadensis*) clones, Tolsted and Hansen (1992) established cutting blocks of stock plants spaced 1 × 1 m in northern Wisconsin. They found that cutting production during the third year was enhanced by more than 200% if they did not harvest any cuttings during the year of establishment, but waited until the second year before harvesting cuttings.

It is desirable that cuttings be harvested during the dormant season and stored properly to maintain their viability. The optimum cutting length is 20 to 30 cm (8 to 12 in.) with a cutting diameter of 1 to 2 cm (1/4 to 3/4 in.) (Meridian Corporation, ca. 1986).

Producing Rooted Cuttings or Plantlets for Transplanting. Sweetgum, black locust, and silver maple can all be rooted using softwood cuttings under high humidity. Silver maple can also be rooted (up to 50%) by using dormant hardwood cuttings stuck directly in the field (Fig. 1 and Preece et al., unpublished). All woody biofuel species discussed in this paper can be clonally micropropagated. If biofuel trees are propagated by softwood cuttings or micropropagation they will be more expensive to the biofuel grower than if hardwood cuttings are stuck directly in the field. However, all propagation methods offer opportunities for the commercial propagator.

The majority of our experience has been with silver maple. We first investigated stem cuttings and micropropagation (Ashby et al., 1987; Preece et al., 1991a) and learned that single node softwood cuttings rooted easily when treated with 1000 ppm IBA in talc, and that micropropagation of this species was not difficult if the phenylurea cytokinin thidiazuron was incorporated into the culture medium.

Figure 1. Root system development on silver maple cuttings stuck directly in the field as hardwood cuttings during the spring. Cuttings lifted and photographed during the early autumn of the same growing season.

Using this information, we selected 90 juvenile clones of silver maple trees that represented the native range of the species. After a single growing season in Carbondale, Illinois, the selected clones were cut into single-node cuttings and placed under intermittent mist, or nodal and shoot tip explants were surface disinfested and placed in vitro for micropropagation (Preece et al., 1991b). There was a significant effect of clone within provenance, both for rooting of cuttings and establishment of the explants in vitro. Cuttings rooted from 26% to 100%, with most clones rooting > 90%.

We tested commercially available auxin rooting formulations on rooting of 2-node, 15-cm-long softwood cuttings of four silver maple clones that were among the most difficult to micropropagate (Table 1). The most consistent high percent rooting and survival of plants after transplanting was when they were treated with a 1:20 dilution of Wood's Rooting Compound. The most difficult to root clone (number 045) rooted more poorly with Hormex, Hormodin, and Rootone than with Wood's; however, the easiest to root clone (number 043) rooted better with the other auxin formulations than with Wood's.

Table 1. Effect of commercially available auxin formulations and clone on rooting and survival of 15-cm-long softwood 2-node stem cuttings of silver maple under intermittent mist.

Auxin (ppm)		Formulation		Trade		Clone	Rooted	Survival
IBA	NAA	Talc	Liquid	name	Provenance	number	(%)	(%)
515	255		×	Wood's (1 : 20) dilution	So. IL	043	77.8	77.8
					So. IL	045	77.8	77.8
					E. Cen.MN	192	88.9	88.9
					Cen. KS	202	88.9	88.9
130	2400		×	Hormex	So. IL	043	100.0	77.8
					So. IL	045	11.1	0.0
					E. Cen. MN	192	100.0	100.0
					Cen. KS	202	55.6	55.6
1000	2000	×		Rootone	So. IL	043	100.0	100.0
					So. IL	045	55.6	44.4
					E. Cen. MN	192	77.8	77.8
					Cen. KS	202	77.8	66.7
3000	0	×		Hormodin No. 2	So. IL	043	100.0	100.0
					So. IL	045	22.2	22.2
					E. Cen. MN	192	100.0	88.9
					Cen. KS	202	88.9	88.9
Significance							*	*

*Significant auxin × clone interaction at the 5% level according to F-test.

Silver maple micropropagation was from single node shoot segments excised from clonal stock plants from the greenhouse. A mean of 65 axillary shoots grew from each explant after 4 months in vitro. The microshoots were rooted and plantlets were transplanted into test plantations for evaluation.

To facilitate scaling up to a micropropagation production level of producing thousands of plantlets for field establishment, clones that did not propagate well were eliminated. Ease of vegetative propagation has also been used to select or eliminate clones of most tree biofuel crops. Therefore, elite clones ultimately used to establish plantations should propagate easily.

CONCLUSIONS

As plantings of woody biofuel crops increase, so will the demand for high quality propagules. The commercial nursery industry should be positioning themselves to supply this potentially lucrative market. Currently the factor most limiting to production is the low number of facilities to use and/or process the biofuels. As fossil fuels become less available and political pressures rise, biofuels will become an increasing important method of harnessing the sun's energy.

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THURSDAY MORNING 3 DECEMBER 1992

The morning session was convened at 8:00 a.m. with Charles Tubesing serving as Moderator.

Production of Recommended Species of Ornamental Grasses

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I have always had a fascination with grasses. However, about 10 years ago this interest took a commercial turn as I saw a developing trend in grasses expanding into a profitable production item. *Miscanthus* and *Pennisetum* were among the first grass plants produced. There are hundreds of species and cultivars of ornamental grasses and grass-like plants and today we are growing about 45 different species and cultivars.

In the beginning we found, as with woody ornamentals that we were more familiar with, there was no one way to produce this wide diversity of plants. In general, we found that producing our liners in raised beds, 4 ft wide with a 6 in. × 6 in. spacing for smaller growing forms and 6 in. × 8 in. or 10 in. for larger growing forms, gave us nice clumps in a single growing season. We also found that by working with 1-year clumps we had a more vigorous plant than from second or third year plants. Beds are set up with overhead irrigation and watered on a regular basis as needed.

We have also found that all grasses do not want nor do they have to be propagated all at one time. When we first started with grasses we tried to do everything in that short window of time as grasses were coming out of dormancy in the spring. Today we still do a vast majority of division in the spring, especially with the *Miscanthus*, but we have found we can spread this project over many different seasons of the year depending on the genus. However, this created a problem in that we now had liners out of sink with our bed lining-out program that would normally take place in late May or early June.

We now pot all of our grass divisions in 2¼-rose pots with small types or 3- in. and 4-in. pots with larger types for root establishment before moving them to beds. The result is an established growing group of liners ready to be planted in beds at the same time whether from April divisions or from divisions made the past August or October and held over in minimum heat houses until ready for early summer planting. This has resulted in excellent stands in our beds. We also grow some species in containers for propagation and divide the overwintered containerized plants in the spring as we would those grown in beds.

We do not market grass liners but grow them for our own internal container production. We annually produce about 60,000 container-grown grasses. They are mostly grown in 2-gal containers, with smaller growing forms like *Carex* and *Festuca* in 1 gal and some of the larger growing forms in 3- or 5-gal containers as specimen size plants. Though we sell some plants to retailers most of our production is directed to the landscape trade or to the large rewholesaler. We encourage contract growing for landscape projects and have produced as many as 23,500 2-gal containers of a single species for an individual project. We like grasses because they work well in our production system and can be grown in the same pine bark based container medium that we use for our other plants.

Advances Using Indole–3–butyric Acid (IBA) Dissolved in Water for—Rooting Cuttings, Transplanting, and Grafting

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INTRODUCTION

Since the 1930s the plant growth regulator indole-3-butyric acid (IBA) has been used in the rooting of cuttings and other growth processes. Other uses for IBA include promoting root regeneration when transplanting plants and to possibly improve grafting success. Concentrations used for rooting range from 10 to 20,000 ppm IBA. The method of use and concentration of IBA is determined by many variables including plant type, time of year, propagation conditions, etc.

Liquid sources of IBA include premixed concentrated liquids containing up to 1.03% IBA dissolved in organic solvents such as ethanol (up to 99.5%) (EPA registrations as of 1992), and water soluble tablets containing 20% IBA which are made into a solution by the grower (U.S. registered Rhizopon-AA Water Soluble Tablets) (Blazich, 1988; Hartmann et al., 1990; Macdonald, 1986). IBA dissolved in water has proved to be more effective for rooting than IBA dissolved in alcohol, or the other auxins, indoleacetic acid (IAA) or naphthaleneacetic acid (NAA) (Blazich, 1988; Hitchcock and Zimmerman, 1939). IBA dissolved in water may be more effective because high concentrations of alcohol can dehydrate, injure, and be toxic to basal stems, scions, and other plant tissues (Blazich, 1988). When IBA is dissolved in a high concentration of alcohol another serious problem can occur. When the alcohol evaporates the concentration of the IBA increases. An IBA concentration beyond the threshold of auxin tolerance will inhibit plant growth (Blazich, 1988).

IBA USED FOR ROOTING CUTTINGS

IBA is applied to cuttings for rooting in powder or liquid formulations. Different concentrations are used because of different plant types, season, and other variables. Methods using IBA in solution are basal immersion, total immersion, quick dip, and spray drip down. It is difficult to relate concentration to root promotion when comparing IBA blended in powders and liquids (Blazich, 1988; Heung and McGuire, 1973; Bonaminoto, 1983; Bonaminoto and Blazich, 1983; Hitchcock and Zimmerman, 1936, 1939). Variation is due to the method of application, retention, and use of the IBA by the plant tissue.

IBA Used for Rooting of Cuttings by Basal Immersion. The IBA immersion method is suitable for hard-to-root plants. It is used to root *Prunus* rootstocks, evergreen and deciduous shrubs, conifers, and *Platanus* × *acerifolia* (London plane) (Macdonald, 1986, ill., pp 345-346). Treatment involves immersion of the basal ends of the cuttings approximately one inch into the solution for 4 to 12 hours. For cuttings propagated under mist the treatment is a maximum of 4 hours. The

cuttings are planted immediately after treatment. For woody and herbaceous cuttings use 50 to 150 ppm IBA dissolved in water.

IBA Used for Rooting of Cuttings by Total Immersion. Total immersion of the cutting produces high quality roots. Treat by immersing the whole cutting in solution for a few seconds and stick the cutting immediately after treatment. For herbaceous cuttings of plumbago, ivy, clematis, delphinium, lavender, and ficus use 50 to 250 ppm IBA dissolved in water.

With stem cuttings of *Berberis, Cotoneaster, Lavandula, Prunus, Pyracantha,* and *Viburnum,* total immersion in an IBA solution has shown better rooting than dipping the basal ends of the cuttings in IBA by the dry dip method. Cuttings were immersed two minutes in 1,000 ppm IBA dissolved in water. The totally immersed cuttings had an increase in fresh weight of the roots when compared to dry dipped (Van Bragh et al. 1976).

IBA Used for Rooting of Cuttings by Quick Dip. Many growers prefer the quick dip method. In this method, the basal ends of cuttings are immersed approximately one inch into a solution for a few seconds. The cuttings are stuck immediately after treating. The quick dip method may produce variable rooting because cuttings are immersed for only a brief time at a high IBA concentration there may be inadequate absorption of the IBA. The following concentrations are recommended:

- Herbaceous, tropical plants, house plants, and roses use 150 to 500 ppm IBA dissolved in water.
- Chrysanthemums use 400 to 500 ppm IBA dissolved in water.
- Softwood cuttings use 1,000 ppm IBA.
- Hardwood cuttings use 2,000 ppm IBA.
- Difficult-to-root hardwood cuttings use 5,000 to 20,000 ppm IBA. A 20,000 ppm treatment with a very fast dip time is used in rare cases for extremely difficult-to-root plants.

IBA Used for Rooting of Cuttings by Spray Drip Down. The spray dip down method is cost effective since it uses minimum labor and low IBA concentration. Cuttings are first stuck in trays. The rooting solution is then sprayed on the leaves and stems until beads of liquid drip down into the medium. For chrysanthemum, begonia, dieffenbachia, heath, and hibiscus use 50 to 250 ppm IBA dissolved in water.

Two Methods to Root Chrysanthemum Cuttings. From 1989 to 1991 the research department at Lyraflor, de Lier, Holland conducted large production tests on the rooting of chrysanthemums. Two methods produced cuttings with high quality and symmetrical root systems:

1) Spray drip down using 5 to 150 ppm IBA dissolved in water

2) Quick dip immersion of the basal end of the cutting for 2 sec in 150 to 400 ppm IBA dissolved in water.

Three Methods to Root Rose Cuttings and Stenting Roses. Research at the Rhizopon Research Center, Hazerswoude, Holland, concluded that rose cuttings produced quality roots by either of three methods (Eigenraam, 1990):

1) Dry dip at 0.25% to 0.6% IBA.

2) Quick dip immerse at 250 to 500 ppm IBA dissolved in water.
3) Spray drip down at 50 to 100 ppm IBA dissolved in water for potted roses.

IBA USED FOR ROOT REGENERATION WHEN TRANSPLANTING ROOTED PLANTS

IBA solutions can promote increased numbers of regenerated roots on woody plants. Optimal concentrations (tested on black walnut, tulip tree, and scarlet oak) for bare root immersion absorption for 5 min were 1,000 to 3,000 ppm IBA. Immersion longer than 5 min or 3,000 ppm IBA inhibited root regeneration and shoot development (Struve and Moser, 1984).

IBA Used for Root Regeneration When Transplanting Roses. Rose crops start with transplanting dormant bushes. Survival of transplants requires rapid root regeneration. Treatment with IBA solutions speeds new root initiation and increases root elongation rate. Survival is improved and there is earlier and higher flower yield. Best results with *Rosa multiflora* 'Kanagawa' were achieved when the roots were immersed for 5 min in 1,000 ppm IBA dissolved in water. The most effective concentration for 'Montrea' on the rootstock *R. canina* 'Inermis' was 500 ppm IBA dissolved in water. Application of NAA or IAA was not found to be as effective (Fuchs and Van Pol, 1986; Fuchs, 1986).

For over 50 years Dutch rose growers have transplanted half-year-old rose bushes using an IBA treatment. The bare roots are immersed for 10 min in 150 ppm IBA dissolved in water or for 5 min in 250 ppm IBA dissolved in water. Water is used as the solvent to eliminate toxic effects from organic solvents. After treatment the rose bushes are planted immediately. At planting time the soil temperature is kept above 60°F and air temperature above 65°F with relative humidity at 80%. Warm soil temperature is a co-factor in utilization of IBA (Fuchs and Van Pol, 1986; Fuchs, 1986).

The Hortus USA Research Center used IBA immersion-absorption when transplanting Simplicity™ shrub roses (Jackson and Perkins, Medford, OR). The treated plants had consistently higher flower yield—up to 60%—over the control plants. Before planting the bare roots were immersed for 10 min in 150 ppm IBA dissolved in water. After treatment the plants were planted in the field. Leaf and stem growth and start of flowering was similar on both treated and control plants. Results suggested that the first stage growth of leaf flush came from stored carbohydrates; the second stage growth of the flowers was influenced by the IBA (Rhizopon Researcher, 1992).

IBA USED FOR GRAFTING

Propagation by grafting of ornamental conifers can be unpredictable and variable. IBA has been used to stimulate cell division at the graft union. Grafts of *Picea pungens* 'Hoopsii' on *P. abies* rootstock were improved by immersing the scion bases for 3 min in 200 ppm IBA prior to joining. Treated grafts were consistently improved by 13% over the controls (Beeson and Proebsting, 1990). Scion wood of *Carya illinoinensis* 'Desirable' (pecan) was successfully grafted onto the lateral roots of 'Van Deman' pecan seedling rootstock by dry dipping the scion in 1% and 2% IBA in talc. Shoot survival for IBA treated grafts was 20% higher than the controls (Yates and Sparks, 1992). Research is necessary to determine if liquid

immersion of the scion will have similar success.

DISCUSSION

IBA dissolved in water is a useful plant growth regulator for the grower and propagator. It is used for rooting of cuttings by dry dip, total immerse, basal immersion, spray drip down, and quick dip methods. Root regeneration is promoted when transplanting rooted plants using IBA by immersion-absorption. It promotes plant growth and higher flower yield. IBA has been shown to improve graft takes of difficult-to-graft plants; studies must be made to determine if IBA dissolved in water is useful. Future developments will come from testing IBA dissolved in water on a wide range of plants, and new application methods and carriers.

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Cell Pack Production of Perennials by Tip Cutting: The Green Leaf Method

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At Green Leaf we produce cell pack perennials by four basic methods: seed, division, root cuttings, and tip cuttings. My talk will concentrate on the Green Leaf system of vegetative tip-cutting propagation with only a brief mention of the other three propagation methods.

We sow seed-grown perennials by two methods—a mechanical seeder and hand seeding in open flats. The bulk of our seeding is by machine, but there are types that are not practical to sow mechanically. For example, it's easier to hand sow the irregular seed types such as large seed (*Baptisia)*, seed with tails (*Gaillardia*), and seed with special needs or long germination periods. After hand-sown seedlings are up, they are transferred to cell-packs.

We do a few plants from divisions—hardy geraniums, *Hemerocallis*, and Japanese anemones. Many divisions, however, are just to big for cell flats.

Root cuttings are used with some *Geranium*, Japanese anemone, *Phlox-paniculata*, *Pulmonaria*, *Aegopodium,* and *Stokesia*. Our root cuttings are done from December through early February. Root cuttings are relatively new for us, so we are still experimenting.

Most of our vegetative production of perennials is done by tip cuttings. We propagate by tip cuttings 12 months of the year. Of course, not every plant can be produced that way throughout the year. We grow cell pack liners in three different sizes—36, 54, and 72. Plant characteristics and needs determine which size will be used. All cell packs fit into a 10-20 tray for standardization of growing and shipping. Therefore, we can use the same shipping box for all plants.

We use only pre-mixed, bagged, peat-lite mixes. It may be cheaper to mix our own growing media, but we find the ease and uniformity of the bagged mixes to fit our needs. Any commercial, well-drained, artificial mix should work for you. If you mix your own, use a Cornell mix. Flats are pre-filled by a flat filler, and then set out for the sticking crews in the propagation houses.

The propagation benches are equipped with Bio-therm bottom heat and electronically controlled mist lines. Soil temperature is kept at approximately 68°F. The mist is adjusted depending on the time of the year, and the specific needs of the plants. Cuttings are misted until root growth is evident by physically testing the cuttings and then turned off. Rooting usually takes 2 to 3 weeks. The rooted cuttings are kept in the propagation house or moved to another warm area, until a full root ball is established. Depending on the type of plant and time of year this can be approximately 6 to 8 weeks. The flats are then moved to a holding area. In the winter, the holding area is run at approximately 34°F at night, to satisfy the dormancy requirements of the plants.

Tip cuttings are taken by production crews from stock plants or mature plants in cell flats. All stock plants are kept in greenhouses where we can control and manipulate their growing conditions. Most herbaceous perennials root best before

flower bud initiation when new, soft spring-like growth is used. We use heat, supplemental lighting, and good cutting techniques to increase the number of cuttings per plant and to lengthen our window of opportunity when cuttings can be taken. We try to take at least a 2-node cutting to ensure good rooting. Smaller cuttings seem to have less vigor and do not root or grow properly. The crews carry plastic wash baskets that they fill with the cuttings. Cuttings, baskets and all, are then dipped into wash tubs containing a solution of K-IBA (potassium salt of indolebutyric acid) and a fungicide. K-IBA is used at a rate of 2 tablespoons per 10 gal of water. Since the demise of Benlate, we have used several different fungicides. Cleary at 3 oz/10 gal or Domaine at 2 oz/10 gal has given us our best results. After dipping the cuttings for approximately 2 min, the crews take the cuttings in the baskets to the propagation tables and stick them into prepared flats.

The rooted cuttings are ready for sale after moving to the holding houses, but may sit on the benches for another 6 months. Storage can become a problem because overgrown or stretched plants can be a haven for insect infestation and disease.

We have developed what we call "the way back machine" which is an electric lawn mower mounted above a moving belt. This machine enables us to easily maintain the flats and produce a bushier, more uniform product. Two people can trim hundreds of flats in a day.

Propagation of Daylilies, Hostas, and Astilbes

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INTRODUCTION

At Casertano Farms in Cheshire, Connecticut our principle crops have been annuals, poinsettias, mums, and Easter and Christmas products. Two years ago we started raising perennials for the wholesale market by utilizing some empty hoophouses used for producing annuals. The houses are 22 × 150 ft and heated with a hot-air system. The first three greenhouses were filled with surplus stock from some of the Holland bulb companies and daylilies from my private farm in Woodbury, Connecticut. We soon had five houses filled with seed perennials. Today, we have eleven greenhouses and twelve acres of land being exclusively used for perennial production.

We irrigate from a large well that eliminates potential algae problems with our micro-irrigation systems, but have a backup pond for use during drought periods. Water is supplied by upright sprinklers placed every 12 ft. Emitters can be changed to increase or decrease the amount of water needed for individual crops. Therefore, it is possible to have plants that require different amounts of water growing in the same row. We leave about 1½ ft between rows and locate the irrigation system in that space. We later use that space to walk and place weights on the edges of over-wintering covers. Heavy-felt covers held down by cement blocks or sandbags are used for winter protection with all our outside 1-qt and 2-gal containers.

Colored pots are used to help customers select the proper planting situation for our perennials. We have orange pots which indicate a sun/light-shade planting is acceptable and purple pots for shade plants.

Depending on the season, we use a crew of 5 to 12 people with a crew of five working straight through the winter growing and dividing plants.

At this time of year, we are busy filling our greenhouses with seedlings and are just beginning to divide other perennials. To maximize the use of our greenhouse space we place racks above the seedlings for *Sempervivum* (hens and chicks) because they like heat and light. They will stay there until early spring, and then be divided again before sale in late spring. By using these racks we accommodate another 8,000 plants in the greenhouses.

PROPAGATION

Field Production for Propagation Material. Field production of plant material for propagation occurs on about about two acres of land which has been rejuvenated with leaf compost. Our nursery has been the town of Cheshire's leaf-recycling center for the past two years and we produce our own compost. We plant double rows on raised beds and place Netafim-trickle tube between the plants. By changing the spacing of emitters—12 in., 18 in., or 24 in.—we can increase or decrease the water to meet individual plant needs.

Container Production for Propagation Material. Propagation in containers is another method we use for raising perennial plant stock. The majority of our

plant material, whether generated by division or seed, is grown in one-quart containers.

Our rows are 10 ft wide by 300 ft long and hold 20,000 qt containers. We have three separate acres covered with black plastic with gravel roads separating each of the three blocks. In addition to the 1½-ft spacing between double rows we also leave a 6-ft wide opening for fertilization or spraying by tractor. In the summertime we place 2 rows of quart trays the length of the roadway so as to maximize the use of the field.

We grow many cultivars of daylily, hosta, and astilbe which are saleable in one year. Astilbes in 9 to 12 months will fill a 1-qt container with their root systems. We used a light bark mix for the 1-qt container and a coarser soil mix for the 2-gal containers. We find very little difference in the mass of the root systems in the two containers (i.e. qt vs 2 gal). By dividing into the smallest pieces possibe, including some pieces that do not have eyes, a 2-gal container can yielded approximately 16 root divisions for planting into 1-qt containers. A 1-qt astilbe has many more eyes than the 2-gal plant, and can be divided into approximately 14 divisions. We have noticed two significant things with astilbe:

1) Plants grown in quart pots generate more complete eyes than those from a 2-gal plant.

2) Using quarts produces approximately four times the quantity in the space used by the 2-gal pots.

Field grown *Hosta* 'Royal Standard' take up more room than 2-gal pots and have problems with weed control. A field-grown hosta plant generates four very large eyes after one year. Each eye is too large to put in a quart pot. This adds another step to our planting process because now we have to cut at least a third of the root stock off the plant before we can use them. The one characteristic that field-grown hostas show, that the quarts and 2-gal containers do not, is lateral eyes on each crown. For example, *Hosta* 'Albo-Marginata' raised in a 2-gal container has 4 crowns exposed, 2-lateral eyes. We take a knife and cut each crown starting from the bottom and drawing the knife to the top. This eliminates damage to any roots at the base of the crown. If done properly, you have cut through the center of the crown with no damage to the roots at the base. These crowns can be halved again for a total of 12 divisions. *Hosta lancifolia* divided from a 1-qt pot yields 8 divisions while an *H. fortunrei* var. 'albo-picta' divided from a 1-qt pot yields about 12 divisions. 'Stella d' Oro' and 'Bonanza' are two daylilies that show the extremes in root growth differences. 'Stella d' Oro' multiplies vigorously and has to be root pruned as their roots are too long. A 1-qt plant will produced five complete fans. These fans, further divided, produced seven additional divisions. Planted at the same time, a 2-gal 'Stella d' Oro' will produce only four fans and take up four times the space. A 1-qt 'Bonanza' will produce only about two fans in one year. By carefully dividing, and keeping small eyes when we find them, a typical 1-qt 'Bonanza' yields a total of seven plants with a little care in cutting. I strongly suggest drenching all hosta and daylily root stock divisions with a fungicide before planting.

CONCLUSIONS

It appears that we are much more productive growing stock plants in 1-qt pots than as 2-gal or field stock. Astilbes and daylilies work well for us using this system. I believe we should look harder at field grown hostas because of their ability to develop more lateral eyes.

Successful Cutting Propagation of *Hamamelis* x *intermedia* 'Arnold Promise' and *Hamamelis mollis* 'Brevipetala'

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Despite their relative scarcity in the American landscape, witch hazels are plants of great merit. These plants can breath life into an otherwise dreary winter garden with their showy flowers and sweet fragrance—with many cultivars featuring excellent fall foliage.

Hamamelis x *intermedia* 'Arnold Promise' and *H. mollis* 'Brevipetala' are two of the finest this genus has to offer. The literature about their successful propagation by cuttings is filled with both controversy and contradiction. Some sources claim this technique is easy while others say it is, if not practically impossible, certainly economically infeasible. In this paper I would like to share some of my experiences, both good and bad, in the propagation of these plants from cuttings.

Rooting Procedures for 'Arnold Promise' and 'Brevipetala'. The rooting of both cultivars is extremely easy. I use semi-ripe cuttings collected in the second week of July. The cuttings are approximately 5 in. long, treated with 8,000 ppm IBA (Hormondin #3), placed under intermittent mist (5 sec/10 min), with bottom heat (76°F). Rooting medium used is a 2 peat : 1 perlite : 1 sand mix (by volume). The cuttings are stuck into 72-plug trays. Though rooting these plants from cuttings is easy, the challenge is getting them to survive and successfully grow on. Once rooted, the liners have a pronounced root sensitivity. The use of plug trays, as opposed to rooting into benches, is crucial.

Initial Failure. I had heard that the rooted cuttings must not be disturbed until after their first dormancy period. The rooted plug trays were removed from the propagation house in August and placed in our liner house where temperatures are not allowed to drop below 32°F in the winter.

I was pleased when the liners began flowering in late January. By late April the cuttings began to leaf out. The trays remained in the liner house until June when they were shifted into 3½- in. peat pots. I was disappointed when the liners refused to put on new growth—seemingly suffering from a form of suspended animation.

The following winter, the plants were placed in an unheated poly-house with the rest of the young nursery stock. That January, after having the audacity to go into bloom, every single 'Arnold Promise' had died—350 plants in all. Out of 350 'Brevipetala' only 15 plants had survived this seemingly inexplicable die-off.

Timing is Crucial. After this crushing disappointment I became determined not to see this happen to my next batch of cuttings that were now sitting in the liner house.

I began asking a lot of questions. After talking to a few people like Jack Alexander of the Arnold Arboretum and Wayne Mezitt of Weston Nurseries it seemed the common belief is that the liners must be shifted directly after bud-break, long before the cuttings fully leaf out.

On April 24th the leaves on my second crop were between 1/8 and 1/4 in. long. The plugs were shifted into plastic quart pots using a bark mulch/sand mix; each were given 6 g of slow release fertilizer. With a certain degree of paranoia after our initial failure, we potted these with extreme care—making sure the plugs remained intact. The fact that our cuttings are rooted into plug trays, as opposed to into a bench and lifted bare root, mitigates the risk of transplanting shock. After shifting into quart pots, the plants proceeded to put on a good 5 to 8 in. of top growth during the summer. The roots now hold a good root ball and seem to be beyond this initial root sensitivity.

I must admit that these are only one-year-old plants and that more research is needed to determine how long this root sensitivity actually lasts. I am told by some growers that I should not shift these quarts until bud break next year, while others, like Ken Twombly of Twombly Nurseries, who raises over 10 cultivars on their own roots, say that these are now stable plants ready for either planting out or shifting up.

If cutting propagation of these *Hamamelis* species proves to be commercially viable, then a more time-efficient method of production exists. Grafted *Hamamelis* are not only slower to produce but also have a propensity towards suckering. If cuttings are left undisturbed for their first dormancy, strict attention paid to leaf development the following spring, and care exercised when shifting, then successful cutting propagation of these witch hazels is possible.

Propagation of *Corylus avellana* 'Contorta' from Root Suckers

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Propagation at Greenbrier Nurseries is primarily devoted to the grafting of unusual Japanese maples. Each year we do about 20,000 units of *Acer palmatum*, as well as hard and softwood cuttings of many rare and unusual woody ornamentals. After grafting *Corylus avellana* 'Contorta' for two years, we found it to be a never ending battle to keep suckers off the young plants. Softwood propagation proved difficult, and plants that did root showed poor root development and were difficult to overwinter the first year. One thing that we did notice, however, was that the rooted plants that we had in production in 3-gal containers showed a tendency to produce suckers the second year. Our annual sales on *C. avellana* 'Contorta' are only about 500 plants per year, so we felt it feasible to develop a system to produce enough suckers to meet our production needs. This system is quite primitive when compared to our bottom-heated greenhouses and outdoor mist systems, but seems to be an adequate and underused way to produce limited quantities of harder-to-root plants that have suckering problems when grafted.

In the early spring (about March 1st in West Virginia) we take our mother plants and cut them back to about 4 in. from the ground. These plants are planted in a bed that contains our potting mixture. This gives the plants a loose soil to produce suckers, and also makes it easier to dig the newly produced plants. After they are cut off they are fertilized with a ½ cup of Woodace fertilizer (3-to 4- month top dress special). The plants are watered liberally all through the growing season. This seems to lead to the development of more shoots. In the summer drought of 1991, we were able to produce far less plants than the previous year under wetter conditions. As shoots begin to emerge, we prune the exiting tip back to promote the growth of the suckers. We see more suckering in early July than any other time of the year. The plants are fertilized again in early October and allowed to go dormant.

In mid-February, the mother plants are removed from the bed and bare-rooted. This allows us to easily remove the sucker with a generous root system attached. Usually we get four to six new plants from each mother plant but have removed as many as eleven plants from one mother plant. The young plants are then potted into 1-gal containers and placed in a poly house where they can be induced to break bud. These plants are usually sold in mid-June as a 1-gal product. Many of these plants will grade out as large as 24 in. tall. We also pot about 200 plants into 3-gal containers. These plants usually show suckers in the pot the second year. We have also removed these young plants from the containers and cut the suckers loose from the root systems in order to obtain additional plants. The mother plants are then planted back into the bed and cared for until the next year.

The advantage of propagating *C. avellana* 'Contorta' by root cuttings is that the homeowner doesn't have to battle the suckers from the understock of a grafted plant. Other plants that this might prove a viable propagation method for in a small nursery are the wonderful cultivars of witch hazel (*Hamamelis*). These plants present many of the same propagation and cultural problems as *C. avellana* 'Contorta'.

Video as a Training/Educational Tool in Plant Propagation Laboratory Exercises

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We are now well into what has been referred to as the information age. Video camera recorders (camcorders) and video cassette recorders (VCRs) are used in many households. People now record on video tape instead of taking moving pictures. This can be instantly played back for checking capture and quality. Videotape has largely replaced movies in the classroom. Numerous commercial tapes are available for plant propagation instruction. Although some of these tapes are well prepared, they are not suited to material available for class use in "hands-on" exercises.

The recent introduction of small, hand-held camcorders makes possible the use of videotapes for individual classes. These camcorders are less expensive and more available to instructors even with modest teaching budgets. Tapes can be tailored to material available and the instructors teaching style to give the students more retention of the presented material. This paper will cover types of systems and equipment needed for taping and presentation of laboratory exercises.

Types of camcorders. Three types of camcorders—Video Home System (VHS), VHS-C(compact), and 8mm—are currently used for home recording. Although the VHS camcorder is used for many home and commercial applications, it is somewhat large and cumbersome for teaching and laboratory use. The advantage of VHS is the tape can be played and edited on the commonly available VCRs. The VHS-C camcorder is more compact and its tapes can be played with a special adapter on regular VHS machines. The standard play tape used in VHS-C can only record for 20 minutes, but this should be sufficient for laboratory exercises. An 8mm camcorder is compact and light weight and 8mm tapes can be purchased to record up to two hours. This camcorder can also be used for playback and editing 8mm tapes, but a small 8mm tape player without a tuner can be purchased for a reasonable amount. This small 8mm VCR makes editing easier and would greatly extend the life of 8mm camcorder tape heads. Any camcorder can direct feed into a VCR for direct recording in a lab or studio situation and save wear on the recording tape head mechanism. I use both an 8mm camcorder and tape player for my laboratory instruction.

A recent check of a video store found all types of camcorders to have models with 8:1 zoom lens with macro capabilities down to size of a 35mm slide picture area. Any camcorder with this lens capability should be sufficient for recording any laboratory exercise.

Monitors. It is practically impossible to tape any demonstration by yourself using only the camera viewfinder. Unless you would like to hire a camera operator, some sort of external monitor will be needed. Any television which allows direct line cabling of the video signal will work. The audio should not be connected as you may get feedback and distorted sound on your recording. Some camcorders have a hot

shoe for mounting a small monitor right on the camera, but these are expensive. I use an older, black and white computer monitor as my video monitor. These are now quite inexpensive and a color monitor is not necessary as most camcorders compensate electronically for all types of lighting and give good color rendition.

Making the Tape. Good photographic technique is important in preparing a demonstration tape. Good lighting and uncluttered background help with the detail needed to communicate well with the students. When you record dark plant material against a light background, the back light switch of the camcorder will often help with detail on the plants. Any camera tripod or copy stand will free your hands for the procedures you wish to show. You should have a script or well thought-out remarks before you turn on the camera. The technique should be rehearsed while watching the monitor until it shows what you want the students to learn. Since this is for your student or employee instruction, it does not have to be a completely finished production. Difficult operations may be taped several times for editing purposes. You probably will edit to a VHS full size tape as this is the common equipment available in classrooms.

Many of us have slides of certain nursery operations. These slides can be taped by projecting on a screen and recording while making comments. Since most camcorders have macro capability you can tape directly from the slide over a light box which will usually give a higher quality recording. Home movies can also be copied from a projected screen image, but copyright laws should be respected with commercial movies.

Advantages of Personalized Videotape. A self-made videotape can demonstrate and have the students complete a laboratory exercise on the same material. Although several commercial tapes are available they may have extraneous material to your educational goals for a particular class time. Since many propagation operations depend on close detailed work, you can show the whole class at the same time. If you demonstrate a particular technique to a class of 20 or more, only 3 or 4 down front pay close attention. The rest are talking or thinking different things. When you show a video tape almost all pay attention. If they did not understand sufficiently, you can rerun the tape until they are satisfied.

Another advantage is when the class is trying a number of different cuttings for a class exercise. The class will not pay close attention to cuttings assigned to other groups. When manipulation of various cuttings are shown on the tape before assignment, the students will pay attention to all of the different techniques since they do not know which they will do for their experiment.

The camcorder is particularly good for showing a whole class small detailed work like embryo extraction or manipulation of tissue-cultured microcuttings. You can zoom in on the manipulations and put on screen what only one or two students could observe closely at one demonstration. If you have a class of 20, this used to mean showing something 10 times or students would have to observe other students. This observation often leads to errors and makes the demonstrating student nervous.

Getting Started. You should visit your local electronics store where knowledgeable sales people can explain various camcorders and taping and editing options. Hopefully, you can get a small teaching grant to help you buy the equipment. You should read the manual carefully and start taping. Although a good photographer

will also probably do well with a camcorder, this technology is in many ways easier than photography. The camcorder can automatically capture an image in almost any light situation, even very low ones. It automatically compensates for color variances in lighting to give an acceptable color image. Focus is automatic, although a bit slow. Finally, you have instant feedback to see if your taped material is usable. If it is not usable, you can try again.

Educational and Other Benefits. The students will benefit from material directed to their instant "hands-on" experience. We are now teaching a generation that gets much of their information from television. Although I firmly believe a college student should be able to learn and interpret information from books, a video helps with practical manipulative skills needed for a profession like plant propagation. Video certainly makes life easier teaching "hands-on" techniques to several students at a time. Commercial propagation operations with large crews may also consider video equipment to bring everyone to the same level of competence. Video can also help review seasonal techniques from previous years for increased early season efficiency.

Integrated Disease Management—Research and Development Using New Techniques and Bioremediation at Vans Pines

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The success of our integrated disease management (IDM) program depends heavily on the skills of the propagation staff.

There are many diseases that can cause considerable havoc in a tree nursery, and some are resistant to fungicides (Sanders, 1989). Costs of controlling some diseases are increasing rapidly as pesticides become unavailable for "minor" users (Spooner-Hart, 1989). During the next few years, there will be more pressure to use alternatives. This presentation is about some of those new alternatives.

I have seen dramatic results using improved cultural practices such as horizontal air in a greenhouse. However, some diseases can be so devastating that preventative fungicide applications are essential to the nursery. Nevertheless, we have found that good cultural practices decrease the amount of fungicide needed.

By restricting watering to as early in the morning as possible, some diseases are discouraged. This can be taken a stage farther in the greenhouse and with an understanding of auto-ecology (Javis, 1989) or micro-climate control, diseases can be cheated from reaching the conditions they need to proliferate. This is exciting work and the literature abounds with information that can be used in practicing IDM (Adams, 1990; Brush, 1990; Campbell, 1989; Glenister, 1989; Graham, 1988; James et al., 1990; Kuack, 1989).

Growing seedlings outdoors is another story. Cultural practices such as the use of drilled beds to improve air movement, clean fields and equipment, good surface drainage, correct fertilization (Engelhart, 1989), and raised beds all help reduce disease pressure. However, we have found that without an effective soil fumigation program, diseases will be a costly problem. Methyl bromide is the fumigant of choice at Vans Pines.

Seed is sown in a timely manner and germination is encouraged as fast as possible by pretreatment of seeds where appropriate. Sprays of one kind or another are inevitable and preventative sprays for some problems are essential. We have tried to use the best equipment to reduce pesticide use and costs. Relentlessly at times, sprayers have to cover the nursery in the narrow window of control necessary to forestall very real problems.

I became convinced of the value of biological controls during a successful experiment we tried in our greenhouses two years ago. A troublesome pest, the shorefly, resisted any kind of chemical spray program until we controlled it with a nematode. The nematode stayed alive and kept devouring our shoreflies until it was no longer a pest. After some research, I discovered that there were also biologicals that could control some of our disease problems. The first documented experiment was published by the U.S.D.A. in 1921 by Hartley (1921). Since then, the last decade has seen a resurgence of interest (Campbell, 1989). It was decided to undertake trials using three different biological products.

The initial experiment took place in the greenhouse. We purchased some medium that was inoculated with GL-21 (*Gliocladium virens*), which is being developed as an effective control for *Pythium* and *Rhizoctonia*. We used this medium to seed several conifer species. It was consumed before the other two biologicals were received so we purchased some GL-21 in prills and mixed it ourselves with sterile medium. The second biological used in the trial was Mycostop, a strain of streptomyces bacteria isolated from Finnish peat which may be used to inhibit *Fusarium* and other diseases. Thirdly, our local practitioners of biological materials supplied us with a genus-specific microbial culture called FAB-29. Samples of all bio-remediations were forwarded to the Pathology Department, Michigan State University and it was determined that each of the treatments contained no harmful substances.

The experimental design included controls and the three treatments in the form of fumigated blocks, dirty blocks, and new blocks. The white styroblocks were spray painted with four colors, one for each replication.

Mycostop was applied as a seed treatment and later as a drench. GL-21 was already premixed in the medium as described. FAB-29A was premixed into the medium and then FAB-29B applied after seeding. After normal block filling and a light pressing, they were seeded with *Picea pungens* 'Glauca'. The automatic seeder also covers the blocks with a fine layer of chicken grit. The blocks were then set on benches and watered with the traveling irrigation boom. The experiment was positioned at the end of a bay so that we could easily ensure that no fungicides would reach them. The seedlings germinated and every cavity was filled. Later the blocks were thinned to one seedling per cavity. No damping off was observed even in the control — the dirty block. Weeks later, some trees in one of the replications did die and there is some indication that *Pythium* was the cause.

The trial was subjected to our normal greenhouse accelerated-growth protocol but has never been treated with any fungicide. Data on saleable trees per treatment will be obtained at harvest time. We will also observe the performance of the trials following out-planting.

In the meantime, my biological suppliers all agreed that I should try the same materials in an outdoor seedbed. This time we agreed to try three different plants—*Acer rubrum*, *P. pungens* 'Glauca', and *Pinus sylvestris*. As the trial was to be in an area that would otherwise receive minimal attention, it was decided to install a drip irrigation system under and above the seedbed. Overhead irrigation was also available, but irrigation scheduling on that particular line would have been too infrequent for germination. The bed was made with irrigation installed 8 inches down. GL-21 and the three genus specific FAB-29B consortiums were incorporated into the seed bed. Mycostop was applied to that portion of the seed lot for each species. FAB-29B was broadcast over the FAB sections. A Love Seeder was used to sow the conifer seeds. The red maple seeds were broadcast and covered with rice hulls. The T-tape irrigation was installed over the bed.

The seedlings all germinated on a Friday. By Sunday, a flock of doves had severely damaged the spruce and pine seedlings. A call to our local biological practitioner revealed another new item: a naturally occurring clear liquid which, even in small amounts, repels birds. It was applied judiciously over the whole works, and the birds, miraculously enough, did not eat any more seedlings. Results at this point, are inconclusive at best. I learned that biological disease control could

be practical either by seed treatment (Harman, 1991), soil incorporation, drenching, or a combination. It would be interesting to apply materials with a mycorrhizal applicator. I also learned that drip irrigation on a seedbed can be useful but the design I followed did not provide even coverage.

My research indicates that there is no silver bullet (Lawson and Dienelt, 1988). The use of just one beneficial organism will probably not work. There should probably be a group of biological components delivered where they can protect the plants when the plants need them. However, research is still limited and fungicides are both sophisticated and inexpensive by comparison. Research into new biological disease controls over the past year has advanced considerably. I am particularly impressed with John Sutton's work in Canada in which *Botrytis cinerea* is controlled by *G. roseum*. The delivery system involves a little footbath of the beneficial spores in talc, which is placed at the door of a beehive. The bees then inoculate the strawberry flowers and *Botrytis* control is achieved (Peng et al., 1992).

Another element of this study was the use of the Alert Diagnostic Kits. As components of an IDM system, these little mobile labs are ideal. Within 10 min, you can identify *Pythium*, *Rhizoctonia*, or *Phytophthora*. They are very user friendly. An electronic meter can also be purchased that quantifies the infection. This small electronic marvel also logs each test for future reference. My only reservation is that they do not identify specific organisms and this could lead to an erroneous diagnosis of a problem (Pscheidt et al., 1992). They also are unable to identify other problem pathogens such as *Fusarium* species. Overall, I think the kits are useful but results should not be considered the last word. Diagnosis of pathogens is extremely complicated and a professional pathologist's diagnosis should always be preferred. The kits allow us to make an educated guess as to the probable nature of the problem fast and in my view are a worthwhile investment.

Vans Pines has been improving cultural practices over the years to produce vigorous, healthy seedlings and nursery stock. The importance of effective insect control, optimum irrigation, and an intelligent nutrition program cannot be overemphasized. Our seedbeds are drilled into ground that has been primed with organic matter, fallowed, and fertilized. Mechanical cultivation, timely weed control, living mulches, root conditioning, and effective insect control are all integral to the production of top quality seedlings.

Compost is produced on-site using modern contracted equipment. This is priceless organic matter. We may not understand exactly how it works, but good compost is very beneficial to the soil.

Another new technique that makes an excellent component of our IDM program was gained from a previous presentation at this region of the I.P.P.S. The old method of growing sugar maple seedlings involved a series of panic frost control measures usually starting in February. This was not a favorite of mine. We tried irrigation, plastic, straw, fumigated straw, and invariably ended with a mess. This year was more than elegant. The Grow Covers keep the irrigation water needed for hard frosts in the aisles, resulting in fewer disease problems. The mini-greenhouses produce 1-0 seedlings that are straight, healthy, and somewhat larger than previous efforts. Grow Covers should also be useful when using biological controls. In addition, many pests are excluded by the fibrous material. Many thanks to Richard Watson for sharing this wonderful system with us (Watson, 1991).

I am currently Nursery Manager at West Wisconsin Nursery where I have already begun new biological trials. We are also using some interesting new biodegradable seedbed covers and living mulches on some fall-seeded red oak.

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THURSDAY MORNING 3 DECEMBER 1992

The morning session reconvened at 10:30 a.m. with Deborah McCown serving as moderator.

Reduction of Nitrates in Nursery Surface and Ground Water

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INTRODUCTION

Nitrogen in an essential element in the production of plants. Management of nitrogen to prevent surface and ground water contamination will be affecting all nursery operations in the future. Some nurseries have already had to address this problem. Nurseries provide a product that is a benefit to the environment, but past and current fertility practices have created environmental problems. Federal and state governments are examining nitrate sources in agriculture and commercial agriculture will most likely be looked at more closely than family farms. Potential problems and some solutions in greenhouse, field and container areas will be discussed. Examples of what Evergreen Nursery is doing to combat these problems will illustrate what has been done in one operation.

GREENHOUSES

Greenhouses have often been considered the area with the least nitrate problem. Large numbers of plants are grown in a relatively small area. High plant density and lack of rain leaching nutrients caused little nitrate to leave the greenhouse. However, recent studies have shown nitrate concentrations in the top 3 ft of soils under some benches to exceed 2,000 lb of nitrogen per acre in decades-old greenhouses (Mcavoy et al., 1992).

Nitrate loss from greenhouses can be reduced by altering the methods of application and types of nitrogen applied. Examples include:

(1) Monitoring fertility levels in the growing medium and applying nitrogen only when the electrical conductivity (EC) or soil test falls below the level required for the crop are necessary to avoid excessive loss. Research to determine the necessary level of nitrogen may be needed.

(2) Subirrigation where benches or floors are flooded during irrigation captures and reuses water and nutrients thus eliminating loss.

(3) Designing greenhouse floors to capture and reuse runoff will reduce nitrate loss.

(4) Drip irrigation is an efficient way to irrigate plants. Water and nutrients are applied only to the pots and not the surrounding surfaces.

(5) Slow-release fertilizers release nitrogen directly to the medium, eliminating loss caused by irrigation runoff from the foliage and surrounding surfaces.

(6) The simple practice of repairing leaky hoses and pipes will reduce nitrate loss from greenhouses.

At Evergreen Nursery, we have worked at reducing nitrate loss by monitoring the EC in our greenhouse crop media. This has reduced the frequency of fertilizer injection during irrigation. It is very important to closely monitor crop growth. We have seen a reduction of growth when EC levels dropped below what the crop requires.

FIELD

Field fertility recommendations in the past were designed to provide a high level of nutrients to the crops at all times. It was cheaper to apply additional nitrogen beyond the crops needs to prevent the financial loss of underfed and undersized plants. With the knowledge that the potential for surface and ground water nitrate contamination exists, new recommendations are necessary to determine the most efficient level of nitrogen needed to grow the crop.

Table 1. Rate of nitrogen application in organic and inorganic forms to test plots.

Year	Total nitrogen lb/A	Inorganic nitrogen lb/A	Sludge nitrogen lb/A	Milorganite nitrogen lb/A
		PL2-4		
1989	300	175	125	0
1990	150	0	0	150
1991	200	0	0	200
1992	200	0	0	200
		PL7-12		
1989	300	125	175	0
1990	150	0	0	150
1991	200	0	0	200
1992	200	0	0	200
		PL70		
1989	300	0	300	0
1990	0	0	0	0
1991	200	200	0	0
1992	200	0	0	200

Development of a fertility program requires an understanding of the needs of the specific crop. Consulting extension specialists at universities and other growers is helpful. The *form of nitrogen, method of application, timing of application*(s) and irrigation program should all be considered. Regular soil sampling may be necessary to determine the correct nitrogen loading. Sampling in and below the root zone will provide information on nitrate loss from the field. Identifying the actual nitrogen removal by a crop will help determine nitrogen needs. A conifer seedbed study showed that 152 to 265 lb N/A was removed from the soil (Iyer et al., 1989). Crop density, type of crop, and weather will affect nitrogen removal. Nitrogen loss can be reduced using drip irrigation, arranging planting beds and

fields to prevent excessive runoff, and filling sink holes which provide an open conduit to the ground water. Knowing the current nitrate levels in the ground water and the direction of flow is information that can affect the amount of nitrogen that is applied annually to a crop. Evergreen Nursery has done extensive work to reduce soil and ground water nitrates. In 1989 a fertility management study plan was developed by Evergreen Nursery to provide the State of Wisconsin data for nitrate management on our site. The birch crop was used to determine the most efficient form and level of nitrogen to apply to the crop. Test plots were set and monitoring wells installed up gradient, two in fields of different nitrogen loadings (Table 1) and one down gradient. Nitrogen was applied in organic and inorganic forms to the test plots. Soil was sampled at 0 to 10 in. and 10 to 18 in. Ground water was sampled every two weeks. Plants were harvested at different times during and at the end of the growing season, and analyzed to determine nitrogen uptake and removal. The crop was measured annually to determine the effect of nitrogen on growth. Irrigation was modified to put less water on more often to prevent leaching of nitrates.

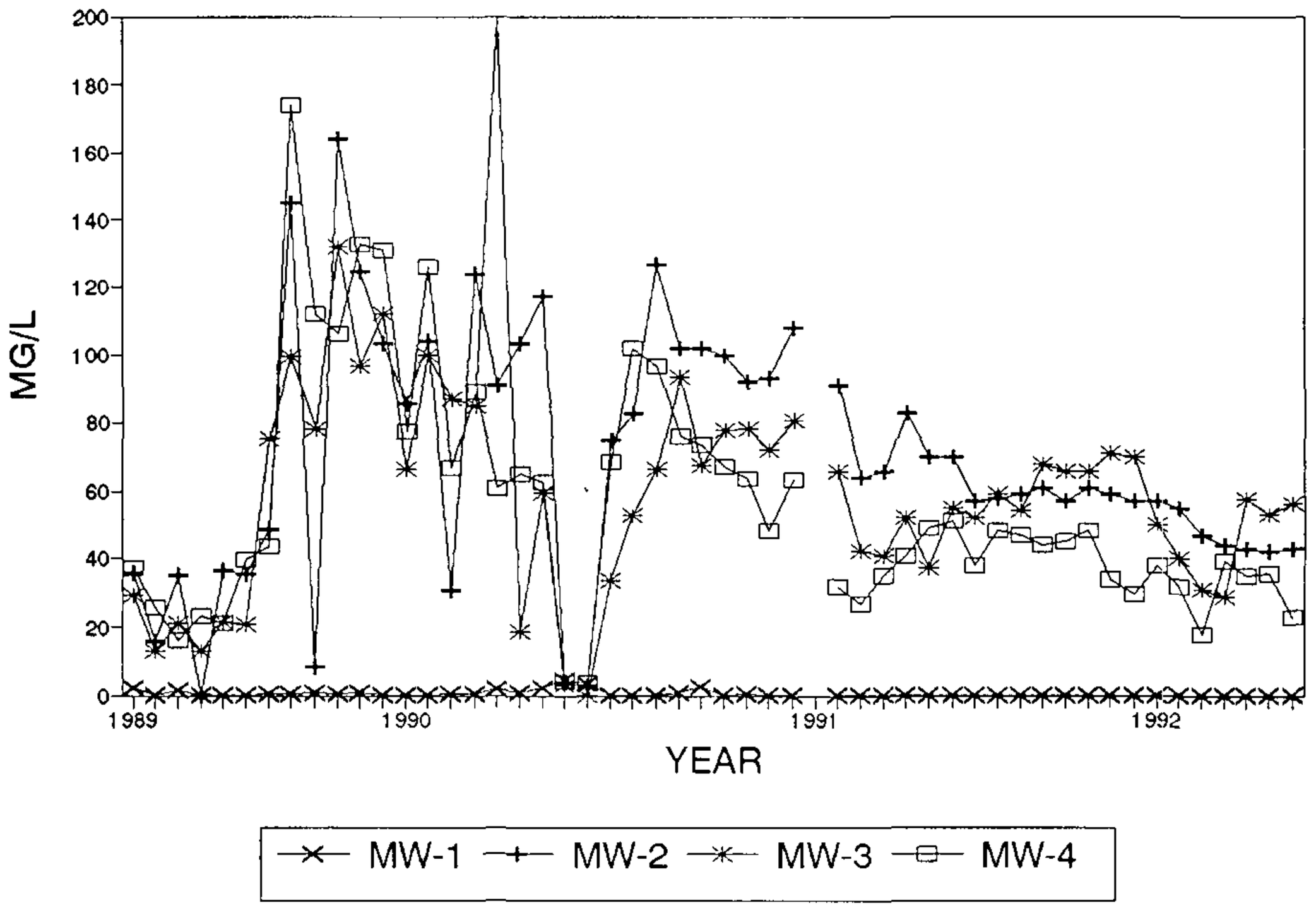

Figure 1. Nitrate-nitrogen levels in monitoring wells 1989 to 1992.

Soil and ground water sampling is ongoing. Monitoring wells have shown a steady decline in nitrates (Fig. 1). Soil nitrates have decreased with a decrease in nitrogen loading. The form of nitrogen applied has affected both the soil nitrate levels and dry weight accumulation (Fig. 2). The initial loading rate of 300 lb N/A was reduced to 150 lb N/A the second year, this caused a decline in growth (Fig. 3) and nitrogen loading was raised to 200 lb N/A. In 1992 all plots were fertilized with organic nitrogen applied as Milorganite.

Conifer field plantings have had nitrogen reductions and applications are timed

to provide nutrients at the estimated time of optimal uptake. The county soils and water conservation department is working with us on a plan to further reduce our runoff and prevent surface and ground water contamination.

CONTAINERS

Container growing areas are a major concern for nitrate runoff. Container media differ from soils in there ability to hold water and nutrients, usually requiring greater inputs of both. Spaced containers occupy only a part of the total surface area. Injection feed systems may waste up to 75% of the nitrogen applied between the pots. Slow-release fertilizers applied directly to the pots eliminate nitrogen between pots, but the irrigation frequency and need to flush water through the pots causes irrigation runoff. Medium rate applications of slow-release fertilizers applied to unspaced pots can represent nitrogen loading rates of over 800 lb N/A. Reducing nitrate loss in containers is in some ways more complex. Efficient irrigation systems are as important as nitrogen application. Application of water through drip irrigation reduces total water use and runoff. Subirrigation contains

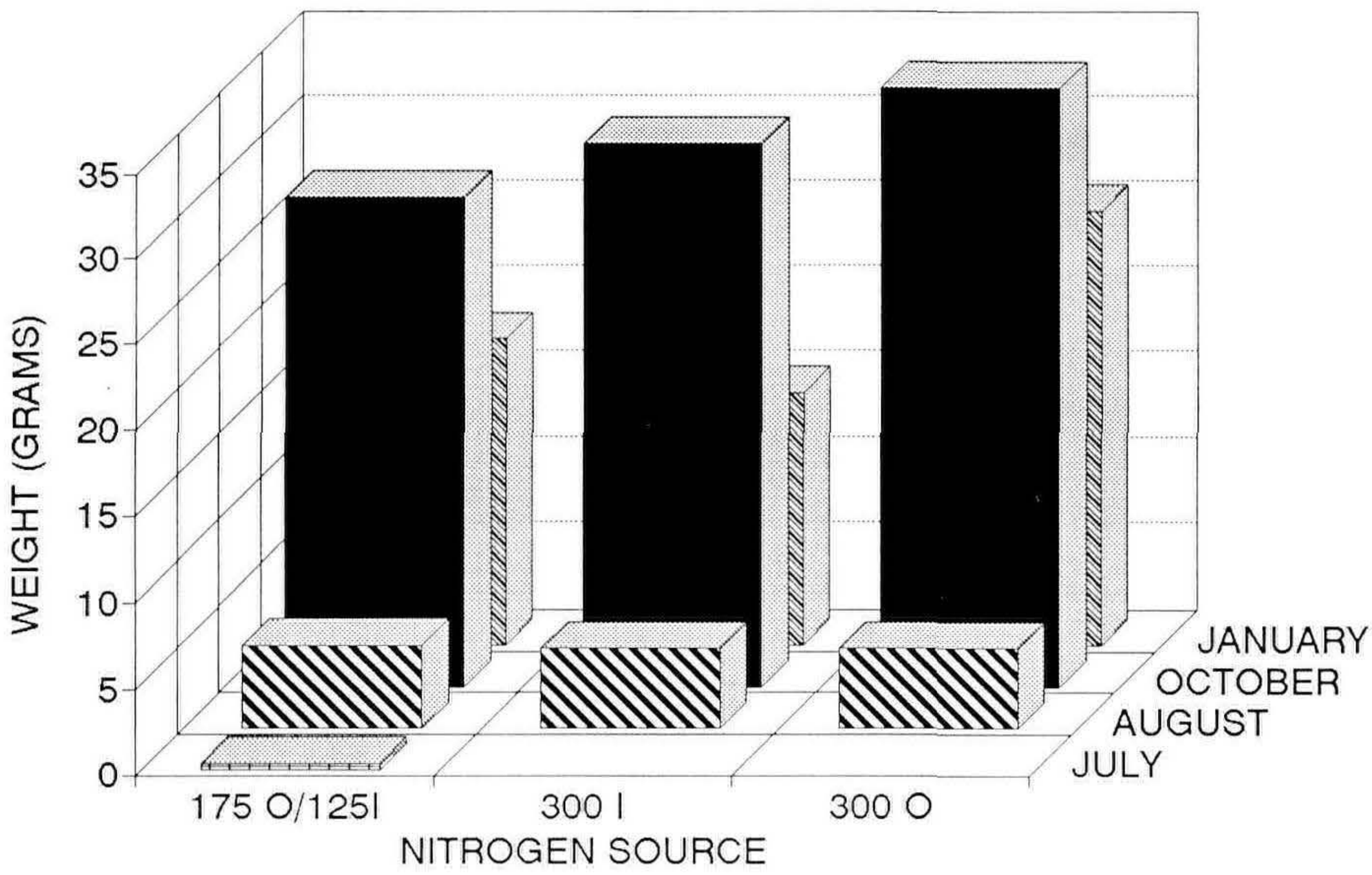

Figure 2. Nitrogen form effects on dry-weight accumulation.

and reuses irrigation water. Watering based on plant need instead of a schedule can also reduce irrigation loss. Altering media for greater water-holding capacity will reduce the irrigation frequency. Wetting agents can increase the rate of water absorption to reduce the length of irrigation.

The method of reuse or disposal of irrigation water will determine the nitrates leaving the container area. Reuse of irrigation water can be done by designing areas so water is collected, treated, and reapplied. This is basically a closed system that can be expensive and may not be possible for many growers. Disposal of

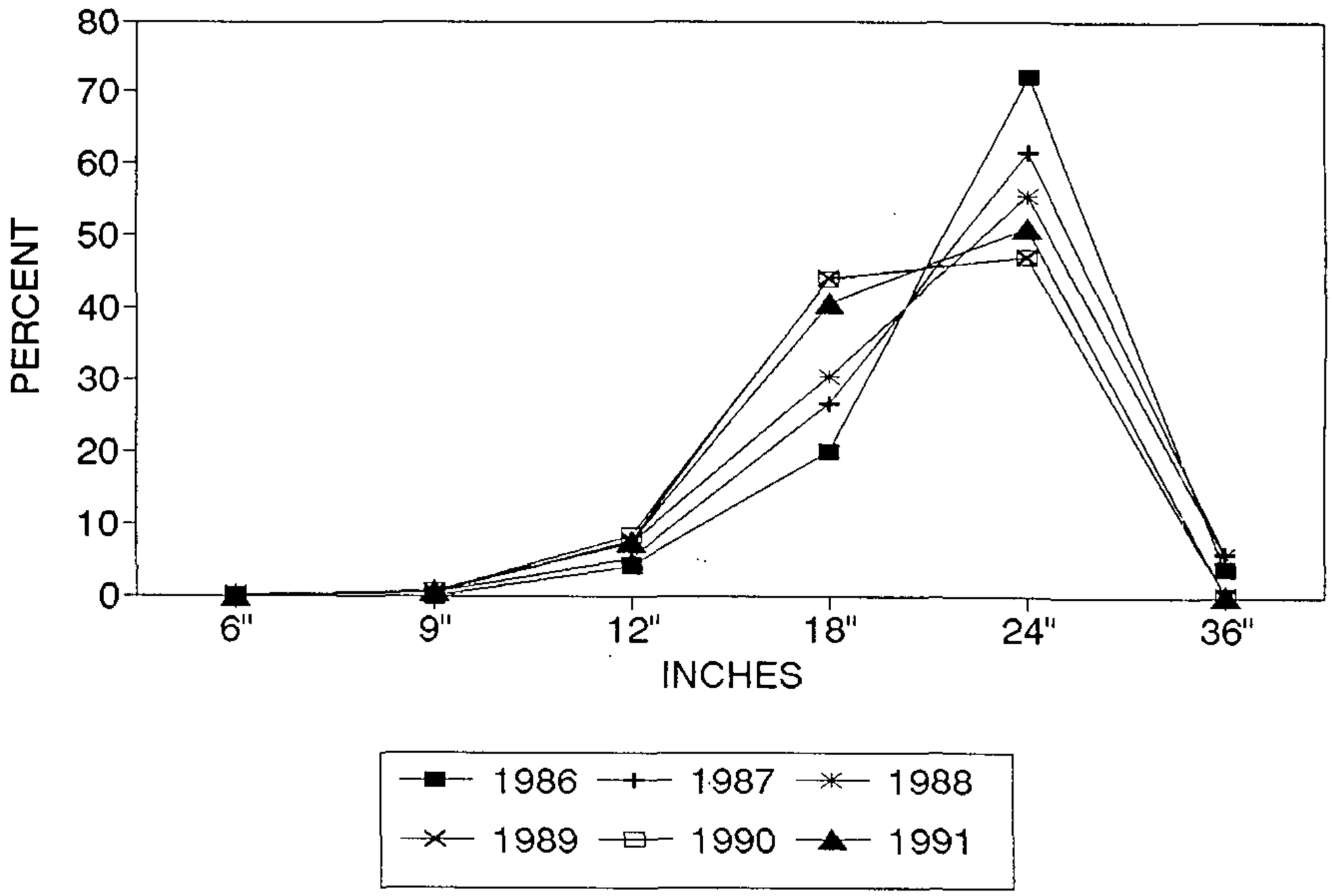

Figure 3. Effect of nitrogen loading rate on growth of birch.

irrigation water can be done by draining container areas to evaporation ponds. Collected water could be land applied to other crops. Wetlands have been looked at as way of reducing nitrates from runoff. Wetlands have been constructed to reduce nitrates and filter water. Municipal treatment systems could treat irrigation water, though this would not be practical in many areas.

At Evergreen Nursery the container operation has switched from injection feed to slow-release fertilizer with injection-feed backup. Water-holding capacity of the growing medium was increased. To determine how much nitrate nitrogen was leaving the container area, pot stands were set up in different locations of the container area to collect irrigation run off from the pot and area surrounding the pot. Samples were collected from slow-release pots and from injection-feed pots. Nitrate runoff in slow-release fertilizer plots averaged 8.6 mg/liter nitrate nitrogen and in injection-feed plots 69.3 mg/liter nitrate nitrogen. This proved the benefit of slow-release fertilizers but also provided data on the loss of nitrates from the container area. Slow-release fertilizers are effective products in providing plant nutrients. In 1992 we have a cooler than normal year. The slow-release products did not release fast enough to provide adequate fertility to the crop. Injection feed was necessary to supplement the nutrition. This reinforces the need to collect and control the runoff from container areas. Evergreen Nursery in currently working with engineering consultants, soil conservation departments, and state agencies to develop the best possible management plan for our nursery.

CONCLUSION

Reduction of nitrates in surface and ground water in nurseries is a complex problem. The best approach is to collect as much information as possible about the nursery and surrounding area. Determine groundwater nitrate levels by testing

irrigation wells. Check the local geological survey for direction of ground water flow to see what other sources are influencing the ground water. If government becomes involved, work with them to accumulate information on needs of your crops. It may be up to the nursery to educate the government agency on nitrogen usage. Nurseries provide an environmentally positive product, and with education and research the production of the products can be environmentally positive as well.

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Sex Identification in Dioecious Woody Landscape Plants

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INTRODUCTION

Dioecious plant species, in which individual plants are either male or female, are commonly used in horticulture. In the majority of these species, the earliest possible identification of sex occurs at the time of flowering, a stage that may not be reached for a number of growing seasons in woody trees and shrubs. Often, one sex is preferred over the other; for example, female hollies are favored because of their attractive fruits, whereas female ginkgos are essentially worthless for landscaping purposes because of their fruits. In those species in which fruit production is favored, it is advantageous to know the sex of individual plants in order to ensure that both sexes are represented in a newly established planting. Thus, it would be of considerable commercial interest to growers to be able to determine the sex of dioecious plants in the seedling stage, potentially reducing the amount of acreage and labor necessary to grow the plants to flowering.

The goals of this paper are twofold: (1) to provide a list of dioecious species used as landscape plants in the United States, and (2) to briefly describe the methods for sex identification that we are testing on dioecious plants.

DIOECY IN WOODY LANDSCAPE PLANTS

Dioecy occurs in a diverse array of taxa of flowering plants (Bawa, 1980; Meagher, 1988). This general pattern is mirrored in a survey of the breeding systems of woody landscape plants. Wyman (1990) lists 45 "genera with flowers dioecious." A complete survey of the plants described by Dirr (1990) increases the total to 51 genera, representing 36 families (Table 1). The overwhelming majority of plant families are represented by a single dioecious genus, but seven (Anacardiaceae, Aquifoliaceae, Elaeagnaceae, Moraceae, Rutaceae, Salicaceae, and Taxaceae) include two to four dioecious genera. The widespread nature of this phenomenon is evident in the fact that 15% of the genera described by Dirr (1990) contain at least one dioecious species. The most important of these genera for landscape purposes are *Ginkgo*, *Ilex*, *Celastrus*, and *Taxus*.

Also included in Table 1 is information on whether the plants are described in the literature as strictly dioecious. In 23 out of 51 genera, there is evidence that some degree of bisexuality occurs. This is probably an underestimate since most detailed studies of the reproductive biology of dioecious taxa reveal some lability in sex expression, as is documented for *Taxus* by Chadwick and Keen (1976). In three species (*Aucuba japonica*, *Ilex opaca*, and *Ruscus aculeatus*) bisexual cultivars have been selected (Dirr, 1990). Although this does not seem to be particularly well documented, in the overwhelming majority of the species listed, reliable fruit-set in females is contingent upon the proximity of male plants.

METHODS FOR SEX IDENTIFICATION

Every method of sex identification is based on inherent genetic differences between males and females. Since few dioecious plant species display sex-linked vegetative characters, one must rely on genomic or biochemical differences that are present in prereproductive plants. The methods that have been applied to plants or are currently being developed include: 1) DNA flow cytometry; 2) biochemical tests; 3) protein electrophoresis; and 4) sex-linked DNA-probe hybridization. We will describe each briefly.

Table 1. Genera of woody landscape plants that include at least one dioecious species. [List of genera compiled from Wyman (1990) and Dirr (1990); species names and breeding systems from Hortus Third (1976), Rehder (1986), and Dirr (1990) and current names and spelling from The New Royal Horticultural Society Dictionary of Gardening (1992).]

Genus	Species[a]	Strictly dioecious?[b]	Family
Acanthopanax	see *Eleutherococcus*		
Acer	*negundo, pensylvanicum*	Y	Aceraceae
Actinidia	*arguta*	N	Actinidiaceae
Ailanthus	*altissima*	N	Simaroubaceae
Aucuba	*japonica*	Y	Cornaceae
Baccharis	*halimifolia*	Y	Compositae
Broussonetia	*papyrifera*	Y	Moraceae
Carica	*papaya*	N	Caricaceae
Celastrus	*scandens*	N	Celastraceae
Cephalotaxus	*harringtonia*	Y	Cephalotaxaceae
Cercidiphyllum	*japonicum*	Y	Cercidiphyllaceae
Chionanthus	*virginicus, retusus*	N	Oleaceae
Cotinus	*obovatus, coggygria*	Y	Anacardiaceae
Diospyros	*virginiana, kaki*	N	Ebenaceae
Eleutherococcus	*sieboldianus, henryi*	N	Araliaceae
Eucommia	*ulmoides*	Y	Eucommiaceae
Fraxinus	*americana, pennsylvanica*	N	Oleaceae
Garrya	7 spp.	Y	Garryaceae
Ginkgo	*biloba*	Y	Ginkgoaceae
Gymnocladus	*dioicus*	N	Leguminosae
Helwingia	*japonica*	Y	Cornaceae
Hippophaë	*rhamnoides*	Y	Elaeagnaceae
Idesia	*polycarpa*	Y	Flacourtiaceae
Ilex	19 spp. + hybrids	N	Aquifoliaceae
Juniperus	10 spp.	N	Cupressaceae
Leitneria	*floridana*	Y	Leitneriaceae
Lindera	*benzoin, obtusiloba*	Y	Lauraceae
Maclura	*pomifera*	Y	Moraceae
Morus	*alba, rubra*	N	Moraceae
Myrica	*pensylvanica, cerifera, gale*	N	Myricaceae
Nemopanthus	*mucronatus*	N	Aquifoliaceae
Nyssa	*sylvatica*	N	Nyssaceae
Orixa	*japonica*	Y	Rutaceae

Table 1. (*Continued*)

Osmanthus	*heterophyllus*	N	Oleaceae
Phellodendron	*amurense*	Y	Rutaceae
Pistacia	*chinensis*	Y	Anacardiaceae
Podocarpus	*macrophyllus* var. *maki, nagi*	Y	Podocarpaceae
Populus	8 spp.	Y	Salicaceae
Rhamnus	*catharticus*	N	Rhamnaceae
Rhus	*aromatica, typhina*	N	Anacardiaceae
Ribes	*alpinum*	Y	Saxifragaceae
Ruscus	*aculeatus*	N	Liliaceae
Salix	*alba* (+ related spp.)	N	Salicaceae
Sassafras	*albidum*	N	Lauraceae
Schisandra	*chinensis, coccinea, Henryi, propinqua*	Y	Schisandraceae
Securinega	*suffruticosa*	Y	Euphorbiaceae
Shepherdia	*canadensis, argentea*	Y	Elaeagnaceae
Skimmia	*japonica, laureola*	Y	Rutaceae
Smilax	8 spp.	Y	Liliaceae
Taxus	*baccata, cuspidata, × media*	N	Taxaceae
Torreya	*californica, nucifera, taxifolia*	N	Taxaceae
Zanthoxylum	*americanum, piperitum, schinifolium, simulans*	Y	Rutaceae

[a]The majority of genera are represented by only one species. For genera with more than one species, the most important or the number of species is listed.

[b]Y = The species listed are always described as dioecious in the literature surveyed.

N = There is some indication that the sexes are not always separate: species descriptions include phrases such as "usually dioecious" or "polygamodioecious," or bisexual cultivars have been selected.

Flow cytometry was originally conceived to facilitate the counting and sizing of particles. One of the most common current applications of flow cytometry is analysis of DNA content in cells (Arumuganathan and Earle, 1991). Nuclei in suspension are stained with DNA-specific fluorescent dyes which emit light when passed through a laser beam. The amount of fluorescence is correlated with the amount of DNA in the nuclei. This technique has been useful for detecting differences in male and female genome size and composition in *Silene latifolia*, a dioecious herbaceous perennial (Costich et al., 1990). There is a 3% difference in total DNA content between males and females of this species, due to the large Y chromosome in males. Using a combination of fluorescent dyes that quantify total DNA and distinguish chemical composition of DNA, we will apply this technique to other dioecious plants. This technique has also shown promise in horticultural studies as a rapid means of determining ploidy level (Costich et al., in press).

Biochemical tests to assay sex-related differences in basic metabolic reactions were developed in the 1920s in the former Soviet Union (Dzhaparidze, 1965).

Unfortunately, Western scientists have not paid much attention to this line of research; however, the simple colorimetric assays that were developed, if their reliability were documented, could prove to be promising for use in the nursery industry.

Electrophoresis, the separation of proteins on the basis of electric charge, is a technique that has been applied with great success to assay genetic variation in plant populations, since allelic forms of enzymes can be identified (e.g. Costich and Meagher, 1992). One class of enzymes in particular, the peroxidases, shows promise for sex identification: there are a few published reports of sex-linked differences in the electrophoretic profiles of these proteins (see references in Meagher, 1988; Zhong, et al. 1982).

A final possibility for sex identification is the use of DNA-based molecular probes. Sex-linked DNA markers based on PCR techniques were recently reported for *Silene latifolia* (Mulcahy, et al., 1992), although the utility of these markers appears to be population-specific. As mentioned above, this species has sex chromosomes; these markers are presumably located on the Y chromosome. The use of molecular genetic techniques for sex identification is clearly in its infancy, and its utility in a horticultural context may be limited by the technical expertise and equipment required.

CONCLUSIONS

The goal of this project is to develop the sex-determination methods described above (particularly flow cytometry) for horticulturally important dioecious species. To achieve this goal we requested plant material from members of I.P.P.S. attending the meeting. Eleven propagators from nurseries and arboretums expressed interest in the project. With their help we will be expanding this survey to adequately sample the diversity of cultivated dioecious taxa.

Acknowledgments. Funds for this research were provided by an Eastern Region I.P.P.S. Research Grant and a William & Kathyrn Heard Grant, administered through the Horticultural Research Institute. We appreciate the advice of Peter Costich and Mary Alice Costich (Horticultural Materials and Systems) and William Flemer III (Princeton Nurseries).

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THURSDAY AFTERNOON 3 DECEMBER 1992

AWARDS LUNCHEON

The Awards Luncheon was held in Pavilion Rooms A-C of the St. Louis Marriott Pavilion Downtown, St. Louis, Missouri.

1992 RESEARCH GRANT AWARD

The Research Award was granted to **Dr. Brian K. Maynard**, Department of Plant Sciences, University of Rhode Island, Kingston, Rhode Island 02881-0804. The title of his grant proposal is "Dose Response Curves and Carrier Effects on Rooting."

CERTIFICATE OF APPRECIATION

President Still presented a Certificate of Appreciation on behalf of the I.P.P.S.—Eastern Region to **Peter Orum** for his effort in bringing about the establishment of the Denmark Region.

INTERNATIONAL AWARD OF HONOR

John Machen, Sr., Vice-President International Plant Propagators' Society, presented the fifth International Award of Honor to **Ralph Shugert**.

FELLOW RECIPIENTS—EASTERN REGION

The I.P.P.S.—Eastern Region named their third class of Fellows' at their 42nd Annual Meeting. Tom McCloud announced the following new Fellows':

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THURSDAY AFTERNOON 3 DECEMBER 1992

AWARDS LUNCHEON

The Awards Luncheon was held in Pavilion Rooms A-C of the St. Louis Marriott Pavilion Downtown, St. Louis, Missouri.

1992 RESEARCH GRANT AWARD

The Research Award was granted to **Dr. Brian K. Maynard**, Department of Plant Sciences, University of Rhode Island, Kingston, Rhode Island 02881-0804. The title of his grant proposal is "Dose Response Curves and Carrier Effects on Rooting."

CERTIFICATE OF APPRECIATION

President Still presented a Certificate of Appreciation on behalf of the I.P.P.S.—Eastern Region to **Peter Orum** for his effort in bringing about the establishment of the Denmark Region.

INTERNATIONAL AWARD OF HONOR

John Machen, Sr., Vice-President International Plant Propagators' Society, presented the fifth International Award of Honor to **Ralph Shugert**.

FELLOW RECIPIENTS—EASTERN REGION

The I.P.P.S.—Eastern Region named their third class of Fellows' at their 42nd Annual Meeting. Tom McCloud announced the following new Fellows':

Mr. William (Bill) Flemer III who was Eastern Region President in 1971-72 and received the Eastern Region's Plant Propagators' Award of Merit in 1973.

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Dzhaparidze, L.I. 1965. Sex in plants, Part 2. (English translation). Israel Program for Scientific Translations and National Science Foundation, Washington, D.C.

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Mr. J. Peter Vermeulen who was Eastern Region President in 1965-66 and received the Eastern Region's Plant Propagators' Award of Merit in 1981.

AWARD OF MERIT—EASTERN REGION

Richard Bosley presented the Award of Merit to **Peter Orum**.

Peter Orum, Midwest Groundcovers, St. Charles, Illinois, was presented the Eastern Region Award of Merit at its annual meeting in St. Louis, Missouri. He served as Eastern Region President for the 1989-1990 year, presiding at the 40th Annual Meeting in Cleveland, Ohio. His most recent efforts on behalf of the I.P.P.S. have been directed at bringing about the establishment of the Denmark Region.

Peter joined the Eastern Region in 1965. He began his service in the Eastern Region on the Long Range Planning committee as both a member and eventually chairman. He next served on the Board of Directors in 1984-1985. After leaving the Board he took on the task of starting the Endowment Committee as its chairman during 1986-1987. In December 1987 he became 2nd V.P. and 1988 1st V.P. and Program Chairman for the Toronto, Canada meeting.

He was born in Soborg, a suburb of Copenhagen, Denmark 4 December 1941. Orum grew up in Vraa, Vendsyssel (most northern province of Denmark) and worked in his father's small nursery.

He also was nursery apprentice at both Spejlborg Nursery and Vilvorde Nursery for four years. He graduated from Vilvorde (Copenhagen) Horticulture School.

In 1965 he arrived in the U.S.A. and held the positions of supervisory trainee at D. Hill Nursery Co., Dundee, Illinois. He later was superintendent of propagation at the same nursery for seven years.

In 1969 Orum and his wife, Irma, began Midwest Groundcovers (the Peter Orum Nurseries) in John Wilde's back yard in West Chicago. He acquired five acres in St. Charles and moved the nursery there in 1970. By 1986 the nursery had grown to 160 acres with 100 acres in production as propagation and container nursery. Orum's nursery annually produces about 10 million plants and employs 80 people in peak season. Midwest Groundcovers is the largest ground cover producer in Illinois.

THURSDAY AFTERNOON 3 DECEMBER 1992

The afternoon session was convened at 2:00 p.m. with Dan Studebaker serving as moderator.

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Taxol—Update 1992

Ralph Shugert
Zelenka Nursery, Inc., 16127 Winans Street, Grand Haven, Michigan 49417

One year ago in December 1991 at the I.P.P.S. Eastern Region in Long Island, I presented a paper with the same title as this one with the exception of the word 1992. I do not intend to repeat last year's words, but I will present a brief review for the sake of continuity.

The key word in the title of this paper is TAXOL, which is one of many taxane compounds. According to a December 18, 1991 Wall Street Journal article, taxol having shown effectiveness against ovarian tumors, "Now appears to be a promising treatment for advanced breast cancer." This statement is predicated on studies conducted by doctors at the University of Texas' Anderson Cancer Center in Houston.

One year ago, I mentioned an organization named "The Alliance for the Production of Taxol", and although loosely structured, it is still viable. This Alliance consists of nursery producers of *Taxus*, Ohio State University (OARDC), and the University of Mississippi. One of many purposes of the Alliance is to convince governmental agencies, and the pharmaceutical industry, that the drug can be economically produced from various plant parts of the ornamental cultivars of *Taxus* rather than destroying our native *Taxus brevifolia* by stripping bark. At an August, 1992 Pacific Yew Conference in Oregon, Dean Bibles, Division of Land Management, stated that 400,000 pounds of *T. brevifolia* is the commitment for 1992. That, good people, represents a tremendous number of irreplaceable trees from our Northwest forests. Best estimates tell us that in three years three million pounds of bark will be harvested! On August 5, 1992, I was in Virgin Flats, Oregon, in an old growth forest and saw 200-year-old, plus, *T. brevifolia* denuded of bark—dead!

Returning to history, starting on January 8, 1992 and terminating on May 15, 1992 the Alliance shipped 40,449 pounds of dry needles/twiglets of *T.* × *media* 'Hicksii' to the National Cancer Institute (NCI). The order was shipped to two NCI contract extractors, Polyscience, New Jersey and Hauser Chemical, Colorado. This was the first movement in the commercial processing of ornamental *Taxus* plant parts. Incidentally, that dry total of 40,449 pounds came from 102,000 pounds of green biomass, and at 0.02% taxol is enough drug to treat 1,250 women.

Obviously, there are a myriad of questions relative to this topic. In reflection, I shall address a few of the most asked questions I have answered in the past four years.

First, and probably foremost, what is the status of a taxol market other than bark, in December, 1992? I have answered this question countless times with this answer: There is, unquestionably, a world wide market for the drug but there is only one United States buyer (Bristol-Meyer Squibb), who is limited by NCI to using bark from *Taxus brevifolia*. In this light, Bristol-Meyer Squibb announced at the August conference in Oregon that they will be "out-of-the-woods" in 1995 and that 30% of the biomass will be from "plantations" (nursery community). I desperately want to believe that statement, however I am skeptical! We all must

be aware that federal approval (NCI) has not been given for drug manufacturing derived from needles rather than bark. Our dreams and aspirations are to have federal approval for the genus *Taxus* rather than specific species, varieties, or cultivars. This is not going to be easy to achieve since there are still a few native *T. brevifolia* trees to rape of their bark. According to Paine-Webber Securities, taxol is a potential billion dollar drug.

A second most asked question is what cultivars of *Taxus* are best for taxol production? Although *T.* × *media* 'Hicksii' is well documented for taxol content, researchers are vigorously exploring the possibility of taxane content in *T. cuspidata*, *T. cuspidata* 'Capitata', *T.* × *hunnewelliana*, *T.* × *media* 'L.C. Bobbink',

PRE-DRYING STORAGE RECORD

TAXUS VARIETY_____

CARRIER:_____ REEFER TEMP ____°F

NURSERY: _____

RECEIVING TIME ____:____AM/PM DATE: __/__/__

FACILITY

NAME/LOCATION_____

BUILDING TYPE_____

INTO STORAGE

TIME ____:____AM/PM DATE____/____/____

CONDITION OF BIOMASS_____

SIGNATURE_____

STORAGE CONDITIONS

TEMPERATURE: MINIMUM____°F MAXIMUM____°F

HUMIDITY: MINIMUM____% MAXIMUM____%

DATA RECORDED BY:_____

OUT OF STORAGE

TIME____:____AM/PM DATE____/____/____

SIGNATURE_____

STORAGE PROBLEMS

PLEASE NOTE PROBLEMS: (MOLD, REFRIGERATION, ETC.)

FRESH WEIGHT

_____POUNDS _____OUNCES OR _____KILO _____GRAM

NUMBER OF PLANTS _____

TIME____:____AM/PM Date____/____/____

DATA RECORDED BY_____

DATE____/____/____ LOT #_____

PRE-DRYING ACTIVITIES

Root Removal_____

Signature_____ Date____/____/____

DRYING CONDITIONS RECORD

INTO DRYER

Time____:____AM/PM DATE____/____/____

OUT OF DRYER

TIME____:____AM/PM DATE____/____/____

PLANT PARTS DRYED

CIRCLE ALL THAT APPLY

NEEDLES STEMS ROOTS WHOLE PLANT

DRY WEIGHT

____POUNDS ____OUNCES OR ____KILO ____GRAM

NUMBER OF PLANTS_____

TIME____:____AM/PM DATE____/____/____

DRYER NOTES

DRYER TURNED OFF: TIME____:____AM/PM

PLANT POSITION IN DRYER: _____

OTHER: _____

DRYER CONDITIONS

TEMPERATURE: MINIMUM____°F MAXIMUM____°F

OUTSIDE TEMP: MINIMUM____°F MAXIMUM____°F

DATA RECORDED BY:_____

DATE ____/____/____ LOT #_____

CHEMICAL SAMPLES

WHOLE PLANT - 1 PLANT PER 1,000 PLANTS
CUT TOPS AND FREEZE

CUTTINGS/CLIPPINGS
FRESH AND FREEZE____
DRY AND FREEZE_____
DRY TO COMMON STORE_____
DRY TO COMMON STORE_____

SIGNATURE_____

DATE____/____/____ LOT #_____

Figure 1. Nursery Field record and storage record for taxus plant parts.

T. × *media* 'Dark Green Spreader', *T.* × *media* 'Densiformis', *T.* × *media* 'Henryii', *T.* × *media* 'Runyan' (Media #8), and *T.* × *media* 'Wardii'. European research is also being conducted using *T. baccata.* Dr. Ed Croom (Mississippi), Dr. Dave Ellis (Wisconsin), Dr. Bob Schutzki (Michigan), and Dr. Nick Wheeler (Washington) are a few of many researchers conducting extensive cultivar evaluations.

A third often asked question would be "Who are the major players relative to this topic?" It is obvious that Bristol-Meyer Squibb (B-MS) is at the top of the list due to their CRADA obligation to NCI. The B-MS facility in Puerto Rico to produce the drug is indeed impressive. Governmental "players" are headed by the National Cancer Institute, and include U.S.D.A., Forest Service, and the Bureau of Land Management. There is also Canadian Government involvement particularly in the Province of British Columbia. Many colleges and universities are exploring various avenues of research largely dependent on grants to supply research dollars. Dr. Dave Ellis and Dr. Brent McCown (Wisconsin) are doing intercellular research to determine where taxane compounds are found in cells. Dr. Ed Croom (Mississippi) is conducting a seasonal hedging study of various Taxus cultivars in production nurseries. Dr. Pete Kaufman (University of Michigan) is doing clinostat studies to simulate microgravity. He hopes to have potted *Taxus* liners in an upcoming NASA space shuttle! Dr. Bob Schutzki (Michigan State University) is including field fertility studies with various rates of nitrogen. Virtually every university in our country has some degree of research in this area. During the recent I.P.P.S. Western Region tour, we saw a poster relative to Dr. Don Durzan's taxol research at the University of California, Davis, California.

Other important "players" include Hauser Chemical Research (Colorado), Indena (Italy), and Weyerhaeuser (Washington). Hauser has stated that in 1993 they will have a production capacity to extract 200 kilos of taxol. Indena is presently a producer for Bristol, and are processing roots of *T.* × *media* 'Hicksii' for an unannounced substance. Weyerhaeuser have had extensive R & D studies for the past five years relative to taxol production via cultivation. They recently published in the "Journal of Natural Products" the taxol content in various *Taxus* species and cultivars. They commented at the August 4, 1992 Oregon conference that field cultivation (plantations) was 700,000 units in 1991, 4,000,000 units in 1992 and perhaps 10,000,000 units in 1993 in Washington.

In my view, *Taxus* growers in the nursery community have a second market for this genus. The early pioneers, Croom specifically, have emphasized biomass from a sustainable source of supply and at long last, certain people are listening to his words. I am attaching to this paper copies of forms used in the Alliance shipment to NCI on the chance that someone in the room might make *Taxus* plant part shipments. These records are very, very important, and Croom and Shugert wish to share this with you.

I wish to close this paper by quoting, in part, from a letter received from Mrs. Claude Petek, Brecksville, OH. "I am a survivor of ovarian cancer because of the drug taxol. In my opinion along with my doctors at the Cleveland Clinic feel I received a second chance on life. I feel that it is a miracle drug that needs to be made available to more women".

There isn't much more to add to those poignant words. Repeating my words of one year ago, "As plant propagators, we once again have the opportunity to utilize the plant parts of *Taxus* to save lives, in addition to beautifying the world." By seeking and sharing we can accomplish this humanitarian goal.

NEW PLANT FORUM

Compiled and moderated by Jack Alexander.

PRESENTERS:

Rob Nicholson, Smith College, Northampton, Massachusetts
Tetracentron sinense

Kris Bachtell, The Morton Arboretum, Lisle, Illinois
Acer × *freemanii* 'Marmo'

John Larsen, Bailey Nurseries, St. Paul, Minnesota
Cornus alba 'Bailhalo' Ivory Halo™ PPAF

John Pair, Kansas State University, Wichita, Kansas
Maclura pomifera 'Wichita'
Cornus florida 'Ozark Spring'

Jack Alexander, The Arnold Arboretum, 125 Arborway, Jamaica Plain, Massachusetts 02130
Styrax obassia

Kathleen Freeland for **Sid Waxman**, Storrs, Connecticut
Pinus strobus 'Sarah Rachel'
Pinus strobus 'Goldie'

Steve McCulloch and **Bruce Briggs**, Briggs Nursery, Olympia, Washington
Oxydendrum arboreum 'Chameleon'
Arbutus 'Marina'
Hosta 'Abiqua Drinking Gourd'
Rhododendron 'Horizon Dawn'

Elwin R. Orton, Jr., Rutgers University, Department of Horticulture Box 231, Cook College, New Brunswick, New Jersey 08903
Cornus florida 'D184-11' Wonderberry®
Cornus florida 'D376-15' Red Beauty®

PLANTS

Plants presented in alphabetical order.

***Acer* × *freemanii* 'Marmo'**, Marmo Freeman maple, is an interspecific hybrid of *A. saccharinum* (silver maple) and *A. rubrum* (red maple). The original tree, located in the plant collections of the Morton Arboretum, Lisle, Illinois, was received from an unknown nursery source in the mid 1920s. It is cold hardy to U.S.D.A. Zone 4. It has a medium-fast growth rate.

It is a large deciduous shade tree with an upright-oval habit and strong central leader. The original tree is approximately 80 ft tall with a spread of 35 ft. Leaf shape

resembles silver maple, but is not as deeply lobed. Foliage is an attractive medium green with a contrasting silver-grey underside and colorful red petioles. Fall color is often an interesting kaleidoscope blend of scarlet and maroon, offset with tints of green. Branch structure and general strength of the plant have proven to be superior to silver maple. No seed is produced.

With the exception of extremely dry locations, adapts well to most site conditions in full sun or light shade. Drought and alkaline soil tolerance are superior to red maple. 'Marmo' is pest and disease resistant as an established landscape specimen. Adaptability and quick establishment make this selection an excellent candidate for residential and commercial sites, especially in the urban environment.

It is easily rooted from softwood cuttings taken in June when treated with 5,000 ppm IBA. Grafting on silver or red maples should be avoided to eliminate the potential of graft incompatibility.

***Arbutus* 'Marina'** is a hybrid of *A.* ×*andrachnoides* and *A. canariensis*. Tree trunk is a satiny, cinnamon color similar to *A. menziesii*. Leaves are dark green, leathery texture, elliptical in shape and 4 to 5 in. long. The drooping, to 6-in., bell-shaped, rose-red flowers are followed by clusters of 2 to 4, bright-red fruit in late fall.

***Cornus alba* 'Bailhalo' Ivory Halo™**, ivory halo dogwood, is an introduction of Bailey Nurseries. It is a compact, rounded selection of variegated dogwood that retains the beautiful green and white variegated foliage in summer and the attractive red twigs in winter. Fall color is insignificant. Ivory halo dogwood is a finer textured, fuller, more compact form that should be useful in smaller landscape areas. Height is 4 to 5 ft with a spread of 4 to 5 ft. It is hardy within Zones 3 to 7 U.S.D.A.

***Cornus florida* 'Ozark Spring'** has been under evaluation since 1975 and just released. It is flower-bud hardy to -22°F (Zone 5) in University of Minnesota laboratory tests. Seedling selection originally from seed collected in Cookson Hills of northeast Oklahoma, by the former Ozark Nurseries of Tahlequah, Oklahoma. It was selected by John C. Pair of Kansas State University out of a population of 125 seedlings having survived the record low of -23°F during 1982 and still flowered. It is upright when young like 'Cherokee Princess'.

Outstanding characteristics include: white overlapping bracts which are more likely to open following dry, desiccating winters; foliage more tolerant of heat under exposed conditions in sunny locations; and excellent wine-red, fall color.

Propagation is by T-budding on seedling understock or softwood cuttings treated with 5,000 to 10,000 ppm IBA in June.

Expected to be best adapted to the Ozark region of Missouri, Arkansas, and eastern Oklahoma but was ready to bloom at Iowa State University when the southern rootstock died.

***Cornus florida* 'D376-15' Red Beauty®.** Plants of this early flowering, red-bracted clone of *C. florida* are semi-dwarf, very dense and self-compacting. The large red bracts are very attractive and provide a spectacular floral display starting in late April in the vicinity of New Brunswick, New Jersey. The original seedling of Red Beauty® resulted from a controlled cross.

***Cornus florida* 'D184-11' Wonderberry®.** Plants of this clone are unusually vigorous, possess thick and leathery, glossy, dark green leaves and are highly

floriferous with an attractive floral display of white bracts in early May. The name Wonderberry® was chosen as the plants produce large, tubular, bright red fruit that are nearly 200% of the size of typical fruit of wild seedlings and other named selections of this species. The original seedling of Wonderberry® resulted from a controlled cross.

***Hosta* 'Abiqua Drinking Gourd'** is a hybrid between *H. tokudama* and *H. sieboldiana*. The foliage is glaucous, large (8 in. × 8 in.) and distinctly cupped like a drinking gourd. Plants grow to 14 in. in diameter and reach 16 in. high. Flowers are white, bell-shaped on scapes 22 in. tall.

***Maclura pomifera* 'Wichita'** is a male, thornless selection found on the Glen Goering farm south of Wichita, Kansas, of moderately upright growth, although suppressed by other nearby trees. The mature 30-year-old specimen is approximately 40 ft tall but would be expected to approach 50 to 60 ft on a good moist site. Leaves are a glossy, dark green, measuring 10 to 12 cm in length and 4 to 6 cm wide. Petiole is grooved, 3 to 4 cm long and contains milky sap as do other parts of the tree. Occasional thorns are produced on juvenile growth, otherwise mostly thornless. A plant known primarily for use in hedgerows and windbreaks, it could be an excellent choice for difficult sites being drought tolerant and pest resistant. Fall color is a good yellow. Tested as far north as Clinton, Iowa.

Propagation by hardwood cuttings is best done in January to March and treated with 5,000 to 10,000 ppm IBA or Hormodin No. 2 or 3 over bottom heat. Softwood cuttings also root easily in May or June with 2,500 to 5,000 ppm IBA. It can be budded in May or August on seedling understock.

***Oxydendrum arboreum* 'Chameleon'** is a chance seedling selected by Polly Hill. At 30 years, it reaches 30 to 35 ft tall with an oval crown. it has a characteristic variable fall color from season to season—sometimes rich red, red to yellow or green, due to early leaf fall. It is hardy to at least Zone 6 U.S.D.A. Briggs Nursery, Inc., Olympia, Washington is the introducer.

***Pinus strobus* 'Goldie'** is also a witches'-broom seedling. Its major attribute is its bright golden yellow foliage. A variegated white pine I have named previously is 'Golden Candles'. 'Golden Candles' is more tree-like and usually has one or two leaders. 'Goldie' is a dwarf shrub with dense branching. Its golden yellow foliage is attractive and remains so throughout the year. It grows approximately 10 in. annually. As with 'Golden Candles', its stems are a bright yellow green. After 12 years of growth it has reached a height of 5 ½ ft and a width of 5 ½ ft. Propagation is by grafting.

***Pinus strobus* 'Sarah Rachel'** was selected from a group of dwarf witches'-broom seedlings. Its major attribute is its form. While most dwarf white pines are broader than tall, 'Sarah Rachel' is taller than broad. Annual growth is approximately 5 in. Its form is ovate with a truncated top. Its branches are all upright and densely arranged. The needles are dark green and appear as thick clusters at each terminal. Propagation is by grafting.

***Rhododendron* 'Horizon Monarch'** is a hybrid between *R.* 'Nancy Evans' and *R.* 'Point Defiance'. Flowers are in a truss of 15 openly funnel-shaped, yellow flowers with a small flare, It has a heavier than average texture. Plant has a spreading

rounded habit, 6 ft wide × 6 ft tall after 10 years. Foliage is elliptical, 6¾ in. long. It is hardy to at least 5°F. This cultivar was bred and introduced by Edwin C. Brockenbrough, Bellevue, Washington.

Styrax obassia, the fragrant snowbell, is native to China, Korea, Manchuria, and Japan where it is reportedly common. It is, however, still uncommon if not rare in the U.S. At the Arnold Arboretum it flowers in late May, displaying terminal racemes of fragrant, white flowers. It normally reaches heights of 20 to 30 ft, occasionally more, and tends to be narrower than tall. A small tree or large shrub well suited to the understory, it grows best in light shade and well drained soil.

The fragrant snowbell is usually considered hardy to U.S.D.A. Zone 6, but Michael Dirr of the University of Georgia has performed laboratory tests of individuals from colder parts of the range and found them to be hardier.

We have successfully propagated it from softwood cuttings and from seed stratified warm for 5 months followed by 3-months cold.

For further information on this and other species of *Styrax* see the article by the same name authored by J.C. Raulston in American Nurseryman, November 1, 1992.

Tetracentron sinense Oliver is a rare chinese tree of the ancient, monotypic family, the Tetracentraceae. It is a deciduous tree and in cultivation in the U.K. has grown to 50 ft while in the wild trees of 90 ft are reported. It is native from central and western China and ranges east to east Nepal. In China it can be found in the transitional region between the northern forests and the mixed mesophytic forests of the south. In east Guizhou it is reported at 1,800 m with such trees as *Fagus longipetiolata*, *Nyssa sinensis*, *Prunus wilsonii*, *Cephalotaxus oliveri* and *Acer sinopurpurascens*. *Tetracentron sinense* has ovate to heart-shaped leaves with a long tapered point. The largest size I have seen is 5.5 in. long by 3 in. wide. The inflorescence, which I have not yet seen, is a slender, pendulous, catkin-like spike with numerous small yellow flowers. The fruit is a deeply lobed capsule. Bean's Encyclopedia describes it as a tree of "great elegance and beauty when bearing its slender catkins around midsummer." Propagation is easy from cuttings. A trial of 40 cuttings (July) in four lots of 10 used treatments of control, 5,000 IBA dip, 10,000 IBA dip, and 20,000 IBA dip, under mist, in sand and perlite (1 : 1, v/v). Rooting percentages were 80%, 100%, 60%, and 80% respectively with the heaviest roots on the first two lots. This material came from J.C. Raulston, who obtained his material from University of British Columbia, Botanical Garden. I would guess that its hardiness could be a Zone 7B U.S.D.A..

EASTERN REGION QUESTION BOX SESSION

The Question Box Session was convened at 2:30 p.m. with Ralph Shugert and Bruce Briggs serving as moderators.

MODERATOR SHUGERT: Is the grafting video that was produced by I.P.P.S.—Eastern Region still available? If so advertise it in our newsletter.

KATHY FREELAND: I have the master of that video if we want to reproduce it.

MODERATOR SHUGERT: Question for Albert Bremer. You stated that you inserted chip buds at an angle. What species do you use this technique with?

MARTIN MEYER: He puts the chip bud in at an angle so that it crosses over to both sides. The cut in the rootstock is not cut at an angle.

MODERATOR SHUGERT: Comment to Ralph Shugert from Dick Bir on rice hulls in media. We did quite a bit of work with rice hulls from an apple processor about 10 years ago. Composting is absolutely needed because: (1) Apple tree seedlings are weeds and plentiful. (2) A yellow mycelial growth from some non-parasitic fungus filled our container mixes. If they ever dried out they were very difficult to rewet and the same mix without rice hulls had no yellow fungus and was not a problem to rewet. (3) More than 20% rice hulls in a pine bark/peat mix reduced growth and increased the need for irrigation. (4) Rice hulls as a soil amendment limited plant growth with evergreen and deciduous rhododendrons when pine bark in the same quantities increased growth. The plants looked fine, i.e. not nitrogen starved. (5) The apple processor stopped using rice hulls so we didn't pursue the work any further.

TIM WOOD: Large amounts of rice hulls tend to stratify in a mix and causes watering problems. There have been some comments that hammer milling reduces that problem.

BRUCE BRIGGS: Remember that there is a difference between rice hulls that have been hammer milled and those that have not been.

MODERATOR SHUGERT: Can anyone relate millimoles of light intensity to foot candles or lux, and describe optimum levels used for acclimating microcuttings? What did you find to be an optimal GA concentration for overcoming *Amelanchier* "stall out."

RICHARD ZIMMERMAN: The conversion can be found in HortScience. 18(6):818-821. 1987.

STEVE MCCULLOCH: We grow several thousand amelanchier and have not seen this "stall out."

ED LOSLEY: We treat amelanchier as a seasonal crop and do not bring them out when the season is short. We bring them out in March.

GAYLE SUTTLE: The amelanchier problem sounds like the problem we have with *Malus*. We solve it by chilling or bringing them out later.

MODERATOR BRIGGS: Question for Gayle Suttle. Do you have any new ways to increase rooting of hard-to-root plants in vitro? On your *Populus* did the roots produce juvenile tops and for how long?

GAYLE SUTTLE: That is too broad of a question. We find that having a healthy vigorous plant is the most important thing. With our microcuttings of redbud, which are difficult for us, we have combined IBA (2,600 ppm) with DMSO for success.

MODERATOR BRIGGS: When you take root cuttings from *Populus* and lay them down are the shoots that arise juvenile?

BILL BARNES: We used to do this with *P. tremuloides*. The shoots that arise are juvenile and can be rooted provided the base is etiolated. If they turn green they probably will not root. You can keep taking cuttings from the roots as long as the roots will produce them.

MODERATOR SHUGERT: Does anyone have successful propagation techniques for *Myrica pensylvanica* by hardwood or softwood cuttings?

BILL BARNES: The secret is to have the best stock plants available. Old plants or older plants in containers root poorly. Take your cuttings off a newly rooted cutting or one-year-old plant. In our case we would root the cutting in June or July, overwinter them, and they would flush into growth around the first or March. That flush is the source of our new cutting material. You can root that cutting and flush it and root that cutting. You can do that 3 to 4 times. Once those cuttings beginning to harden off as the day length begins to shorten. The trick is to get the cuttings before the daylength begins to shorten. The cuttings should be butter soft or snap like a string bean. Between the months of March to the middle of June in Pennsylvania.

MODERATOR SHUGERT: Has a procedure for successful tissue culture propagation of *Taxus cuspidata* 'Capitata' been developed?

RICHARD ZIMMERMAN: None that I am aware of.

RALPH SHUGERT: Zelenka Nursery did provide a grant in 1979 and 1980 to Michigan State University and Dr. Ken Sink. He was unable to produce roots or shoots *in vitro*.

MODERATOR SHUGERT: Is anyone rooting *Corylus avellana* 'Contorta' from cuttings?

DIXON HOOGENDORN: We did some this year very successfully in the greenhouse. In our outside mist beds we were not as successful. It was a cool and

wet summer. We rooted them in sand and have potted them up and have placed them in our overwintering frame. The cuttings were taken about the first week of July and treated with Hormodin #2.

MODERATOR SHUGERT: Has anyone had success rooting *Clematis texensis*?

STEVE MCCULLOCH: We have tissue cultured some of the cultivars and had no problem rooting the shoots out of culture under mist. It took about 2 to 3 weeks.

MODERATOR BRIGGS: My *Styrax japonica* cuttings were direct rooted into pots in June. I got an excellent stand. However, I have had difficulty overwintering them. How can I successfully overwinter them?

BILL BARNES: It is best to get that cutting rooted as early as possible in the summer or late spring as you can. Sticking stock plants in a greenhouse is a possibility to get cuttings early. Root the first of June with as low a hormone concentration as you can get away with. Higher hormone concentrations tend to cause a latent bud dormancy. If your stock plants are under long day, put cuttings under long day and once they are rooted they will break bud and keep growing. The regrowth should aid carbohydrate storage which helps get them through the winter. If they fail to break bud the rooted cuttings may not have enough carbohydrate to make it through the winter.

BRUCE BRIGGS: We have had a problem with tissue cultured plants. Some times we will get them to 2 ft tall and they will not overwinter. It could be a storage problem.

TOM MCCLOUD: We have had success with hardwood cuttings from water sprouts taken in January, stuck in the greenhouse, in peat and perlite with bottom heat, and Woods Rooting Compound at the rate for hardwood cuttings. By spring or early summer they are rooted. The sprouts were taken from an old tree and had a heal at the base.

BRUCE BRIGGS: Questions for Mark Richey. Had it been determined that your slow-release prills were "spent" as a result of faster-than-expected release? Are you working with other brands of slow-release fertilizer?

MARK RICHEY: There are probably as many problems as there are brands. My contention is that it is not the nice neat package that is being marketed to us. We have to understand that the growing conditions that we will put the slow-release fertilizers under will vary from one nursery to another. Based on my observations in pots and containers I am lead to believe that there is a quick release when the fertilizer contacts water. There is not a nice even release during the whole life of the product. The technical rep said the prills were empty in answer to that part of the question.

MODERATOR SHUGERT: Question for Mic Armstrong. What is the biocontrol for birds and where do you get it?

MIC ARMSTRONG: I am not sure of the name of the product for bird control. With the GL-21 it cost $3.00 extra for the two 50 cubic foot bags.

DAVE BAKKER: For spring seeded plants, such as spruce, we wet the seed and put pure maneb and plant the seed. When the seed germinates the birds will not eat the germinating seeds.

MODERATOR SHUGERT: You mention seven group of plants that you arrange according to their needs such as watering. What are the seven groups.

MARK RICHEY: One group is those that have leaf problems. Another group is those that have root problems if kept to wet. Those that you want to keep cooler in the spring because they are rapid growers would be another. It would be those types of plants. It is the first year that we have done that and we may expand that next year.

MODERATOR SHUGERT: Question of Ed Croon. In our life time do you think that we are going to see taxol in a bottle from cultivars of taxus?

ED CROON: Yes.

Abnormal Growths on Micropropagated Elepidote Rhododendrons

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INTRODUCTION

The occurrence of abnormal growths or tissue proliferations (TP) on elepidote rhododendrons has been the subject of intense discussion at formal and informal meetings around the country and in nursery-related publications (Anonymous, 1992a; Anonymous, 1992b; Bayer, 1982; LaMondia et al., 1992; Rostan, 1992). Unfortunately, the information on the identity, significance, the mode of transmission, and cause of TP has been conflicting.

Experimental evidence is required to prove how damaging TP is to plant health. Observations in Ohio suggest the vascular system of stems with large TPs is disrupted, resulting in weak plants which cannot be sold. Plants with TPs on the upper trunk and branches are cosmetically unacceptable and may also be weakened. We will review some of the conflicting observations and speculate on possible causes of the TPs. References will also be made to reviews on topics covered here to provide those interested with a more comprehensive background.

CHARACTERISTICS OF TISSUE PROLIFERATION

The term "tissue proliferation" or TP is applied to the abnormal growths characterized as callus-like tissue with adventitious buds and/or shoots ("shooty") which are typically produced at the crown of plants. In Connecticut, efforts have been made to distinguish TP from crown gall whose diagnosis can lead to destruction or rejection of plant shipments into the state (LaMondia et al., 1992). This effort led to a preliminary conclusion that crown gall and TP could be distinguished by the characteristics summarized in Table 1. While these characteristics may apply in some cases, it is not yet certain they are clearly diagnostic as they rely on limited definitions of both TP and crown gall on rhododendrons.

Historically, crown gall has not been seen as a significant problem on rhododendrons and proofs that specific symptoms represent the disease are lacking. Well documented studies on crown gall of tobacco show that the symptoms of disease resulting from infection by *Agrobacterium tumefaciens* can vary from shooty to non-shooty tumors (Hooykaas et al., 1982; Landman, 1991; Morris, 1986; Turgeon, 1982). Genetic tumors in tobacco, which develop in the absence of pathogens, produce a similar range of symptoms, but tend to produce shoots ("shooty") from the tumor cells (Bayer, 1982; King, 1991). It has been demonstrated that *A. tumefaciens* induces tumor formation by inserting into host DNA the cytokinin biosynthetic isopentenyl transferase *ipt* gene (Ichikawa and Syono, 1991; Morris, 1986).

However, certain tobacco species contain a gene functionally equivalent to *ipt* in the absence of infection (Ichikawa and Syono, 1991). An analogous situation exists for the *roi* gene of *A. rhizogenes* which functions in auxin biosynthesis (Ichikawa and Syono, 1991) and induces tumors with root ("rooty") outgrowths, but a functionally equivalent gene can also be found in certain uninfected species of tobacco (Ichikawa and Syono, 1991).

Table 1. Characteristics initially used to distinguish tissue proliferation from crown gall on elepidote rhododendrons. These criteria are now in question.

Tissue proliferation	Crown gall
Adventitious shoots on tumors	No shoots on tumors
Organized vascular tissue	Unorganized internal tissues
Nodular, semiorganized, meristematic portions of tumors	No meristems or nodules on tumors
Tumors not seen on roots	Tumors present on roots

It is doubtful that degree of vascular differentiation can be easily used to distinguish TP and crown gall. Although the vascular tissues in crown gall proliferations are disorganized, similar disorganization has been observed in microscopic examinations of putative TPs in a range of sizes (David Leach, personal communication). Experimental evidence is also required to establish whether root tumors only occur in cases of crown gall. Root, crown, and aerial proliferations have been observed in plants putatively identified as having TP (personal observations and personal communication with David Leach). It is premature to exclude the possibility of TP symptoms on roots.

CAUSES OF TISSUE PROLIFERATION

If TP and crown gall are distinct, it is not surprising that a similar range in symptoms can result, since the biochemical and developmental processes producing cell proliferation may be similar (Bayer, 1982; Hooykaas et al., 1982; Ichikawa and Syono, 1991; Kung, 1991). To date, artificial inoculations with *Agrobacterium* isolated from elepidote rhododendrons and molecular probing for biovars of *Agrobacterium* have proven negative, or inconclusive. Similarly, in our lab and others, attempts to isolate bacteria from in vitro rhododendron cultures known to produce a high frequency of TP plants have proven negative. However, the striking similarity of symptoms produced in the case of crown gall and TP suggests if a strain of *Agrobacterium* is not involved, a similar disruption in normal metabolism has occurred.

If TP is not the result of crown gall, it may be induced by any of a number of other pathogens known to induce galling and brooming in ericaceous and other woody plants (Eck and Childers, 1966; Farr et al., 1989; Sinclair et al., 1987; Wicker, 1987). Observations in the northeastern U.S. suggest that TP is found almost exclusively in micropropagated plants. Plants produced by cuttings from non-

tissue culture stock plants, or seedlings, have not produced TP symptoms. However, not all tissue cultured rhododendrons develop TP. If biotic agents are involved in inducing TP, it is curious why tissue culture plants would be infected at a higher frequency than rooted cuttings or seedlings. There are contrasting claims that TP is produced on microporpagated plants, rooted cuttings, and seedlings of elepidote rhododendrons and that proliferations are similar to burls which are a natural mechanism of plant regeneration.

The comparative incidence of TP in a cultivar propagated by cuttings and through micropropagation needs to be established. Until the experimental results are known, we take the precaution of considering all micropropagated plants from batches showing TP as being suspect of having the capacity to develop and transmit the capacity to develop TP. This is only a precaution, but emphasizes the importance of research on the transmission of TP.

Observations made to date are in general agreement that TP is not highly contagious and is confined within a cultivar showing the problem with no spread to adjacent plants (Anonymous, 1992a). However, a nursery has reported that rooted cutting produced from stock plants with TP also develop TP. While there are also reports that TP is not transmitted through cuttings (Anonymous, 1992a), these results show it is necessary at present to know the propagation history of stock plants used for cuttings. Until experimental evidence clearly establishes the safety of using TP plants or non-TP plants from the same production, it is wise to only use stock plants that are (a) known to derive from cuttings tracing back to the original plant or (b) from micropropagated plant batches that have not shown TP. The need for careful records is essential until more is known.

TISSUE PROLIFERATION IN THE ABSENCE OF PATHOGENS

It is possible the expression of TP in the northeastern U.S. is enhanced by environmental stresses since some nurseries have had to discard plants due to their declining vigor. In contrast, nurseries in the Pacific Northwest have not seen a lethal decline in plant vigor. We observe that symptoms in Connecticut can vary among and between cultivars from being shooty, weakly shooty, to non-shooty or various combinations of these symptoms. Table 2 is a summary of characteristic symptoms observed in some cultivars. TP differs from burls in that the proliferations appear to lose their ability to organize normal meristems, buds, or shoots. Similarities can be drawn between such symptoms and the production of tumorous growth in tissue culture in the absence of pathogens (Gaspar et al., 1991). It has been observed that normal habituated callus (callus no longer dependent on presence of hormones for proliferation) is capable of organizing meristematic centers and organogenesis (totipotent); however, this ability can be lost progressively, passing next to a stage where totipotency is partly lost (eg., vitrified shoots), and finally to an irreversible stage in which totipotency is irreversibly lost (Gaspar et al., 1991).

If TP is not caused by an infectious agent, we speculate it requires a combination of (a) a genetic susceptibility to TP (a TP gene?) and (b) an alteration in normal genetic regulation in rhododendrons. It is known that the frequency and phenotypes of proliferations can vary among rhododendron cultivars which leads us to suspect a genetic basis in which some cultivars are highly susceptible and others relatively resistant. The genetic basis can be established by transmission genetics.

Table 2. A summary of characteristic symptoms observed in some rhododendron cultivars. This list is by no means all-inclusive and listed cultivars do not always develop tissue proliferation symptoms.

Rhododendron cultivars and tissue proliferation symptoms
'Album' Basal tumors accompanied by large numbers of small shoots, meristems or nodules.
'Scintillation' Basal tumors accompanied by a moderate to small number of short/compressed shoots, meristems or nodules. Occasionally shoots will be absent on tumors.
'Bessie Howells' Basal tumors usually without associated shoots or meristems. Occasionally shoots may be found on tumors.
'Solidarity' Tumors found at base of plant and on aerial portions of plants. Shoots on tumors have not been observed.

Epigenetic changes involve changes in gene expression due to altered genetic regulation. Habituation is an example of an epigenetic change in which cells grown in vitro on hormone-containing media (cytokinin and auxin) lose their requirements for the hormones (Ichikawa and Syono, 1991; Kung, 1991; Meins, 1989). The cells that once required exogenous hormone become hormone autotrophic. Tobacco cells transformed by *A. tumefaciens* behave as habituated cells, but cells that are not transformed can also become habituated. Studies on genetic tumors of tobacco show there are 3 steps in tumorigenesis: (1) gene for tumorigenesis must be present in the plant; (2) stress initiates additional cytokinin synthesis; and (3) the interaction between additional cytokinin and the tumorigenesis gene to induces abnormal growth (Kung, 1991). This scheme has been further refined to include regulation of the auxin metabolism in tumorigenesis (LaMondia et al, 1992).

If there are genetic tumors in rhododendrons, the mechanism may differ slightly from the model for tobacco. First, it appears that tissue culture propagation as well as the host genotype is important in making a cultivar highly susceptible. An epigenetic change or habituation (in extreme cases) may be induced during in vitro culture. Although the molecular mechanism of habituation is not known (Meins, 1989), it is known that tissue culture can activate transposable elements in maize which alter gene expression (Lee and Phillips, 1988). Similarly, other mobile (Landman, 1991; Weil et al. 1990) and nonmobile genes (Sachs and Ho, 1986) can alter the normal progression or regulation of gene expression. If an epigenetic change has occurred, a rhododendron may fully express its degree of susceptibility to TP. Environmental stresses (biotic or abiotic) or internal stresses (flowering) may then trigger the next stage (full habituation?) that would result in TP.

We have observed, along with others, the production of in vitro proliferations in the rhododendron cultivar 'Montego'. 'Montego' produces a high incidence of TP on plants in nursery production. 'Montego' will also produce shoots in vitro in the absence of auxin and cytokinin. One can speculate that this highly susceptible cultivar is fully habituated in vitro, a state that may not apply to most cultivars. TP may be an expression of the fully habituated state in rhododendrons containing TP susceptibility genes and genes which will effect epigenetic changes.

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Excellence in our Educational Environments

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Self reliance, initiative, creativity, and risk taking can justifiably be used to describe those who created the U.S. as well as other free societies that exist in our world today. I feel I personally owe a great deal to those who have gone before me to provide the opportunities that I enjoy today. One of these being our educational system. Our educational system in the U.S., as flawed as it is, still has the potential to provide each individual with many of the necessary tools they require to live a happy, successful life. However, as individuals we have become more reliant on others (government, business, etc.) to provide for individual needs such as transportation, health care, and education. Have we also begun to forget that our ultimate success/happiness is actually up to no one else but ourselves? The project this paper describes was designed to recapture the spirit of adventure in learning and most importantly develop the "I can" spirit in our children as well as some adults that may have temporarily misplaced it, while also improving our educational system.

As a group of parents/teachers at our local elementary school (Henderson Elementary in St. Peters, Missouri, part of the Francis Howell School District in St. Charles county, Missouri) we began to ask the question. What can we do to help improve the learning environment of our relatively new school (5 years)? Many individual projects were discussed, but when you looked closely at each they all fit into one or both of two categories. One would be to improve parent/teacher/student relationships, the second to develop a renewed interest or enthusiasm for learning. Millions of dollars invested in buildings and books do less to enlighten our children if learning itself is not fun and interesting. Also, teaching is not merely the responsibility of our teachers, but also the parents and other adults our children come into contact with.

Since our school was new and little to no district money had been spent on landscaping the building, we were left with a multi million dollar facility that appeared sterile and drab. Not a very pleasant place to see or much less a place where our children and teachers were to spend their creative time. This is where we were to develop the builders, sculptors, doctors, and other future shapers of our society. With an exception of less than 1%, everyone felt the appearance of the school should reflect the creativity, imagination and vision of hope that we had for our children. However, few wanted to spend the money required to provide such a place. Therefore, we would not spend any tax money on the project. The only source of funding for the project would come from those individuals, groups, or business who wanted to support the effort.

Our first project was to start developing a shade tree base around the school. The area available for planting covered approximately 14 acres. We could have placed hundreds of trees around the building that housed more than 800 students and 75 staff. However, our first adopt-a-tree program provided 40 shade trees for the front of the school building. Each tree (1 to 2 in. in caliper) was purchased through a local

nursery that provided them at wholesale cost to individuals or groups that would plant them within the school grounds according to the specifications of a shade tree plan that was developed.

This first fall tree planting was a tremendous success. The estimated 100 plus individuals involved in the planting spent an enjoyable Saturday afternoon improving not only the appearance of the school but the relationships between student, teacher, parent, grandparent, etc. The excitement of this enjoyment buzzed through the school community in the following months and a call for another larger project came from a growing number of interested individuals and groups.

Because of this increased interest a larger plan to develop the entire front of the school was formulated though the ideas of everyone who was interested and with the help of professional landscape planners, horticulturists, irrigation specialists, etc. This project was broken into three phases or sections to allow for an orderly implementation of the plan given various levels of support that might develop. The entire project would encompass some 260 plus plantings of bulbs, shrubs, trees, and vines. An adopt-a-plant program was implemented to support the program. This allowed individuals or groups to sponsor plants ranging in cost from $1.00 to $75.00. To our surprise every plant was sponsored for the upcoming spring planting. The parent teacher organization then provided the funds to purchase the $5,000.00 irrigation system that would be required. Companies such as Chemlawn and Monsanto donated the use of equipment and resources to complete the necessary requirements for the project. After receiving final approval to proceed from the school board, a date for the planting was set.

Approximately 300 plus individuals spent a pleasant spring day toiling to move 90 cubic yards of poor soil from selected areas and replacing it with topsoil, installing the plant material as well as an irrigation system, and mulching the area.

This project was an even larger success than the first fall planting. To have been a part of it was a great source of pride for everyone within the school community. The excitement of our increasing group of supporters began to grow and the call for another project soon came.

During the coming months the finishing touches would be placed on a comprehensive forestry plan for the entire facility while the development of ideas and planning for an innovative outdoor study facility would grow. The planning for these projects, as for the earlier ones, were driven by and reflected the interest and thoughts of the entire school community. Parents, teachers, and students from kindergarten through the 6th grade that shared our building were all given an opportunity to present ideas and mold the approach we took.

As we continued to plan we became aware of a grant that was available for tree plantings such as the one we were hoping to complete at our school. The grant was available through the Missouri Department of Natural Resources—Division of Energy. It was known as T.R.E.E. or Trees Renew Energy and the Environment. We prepared an application and submitted it. To our surprise our request for $16,000.00 was doubled by the review board. They felt that the previous success of our group and the scope of our plan had merit for their effort in teaching the importance of energy efficient landscaping. We were allowed to increase the number of species and number of trees in our original proposal as well as provide funding for another school's planting through our effort.

Funds to provide the required irrigation system for the 850 plus trees that would be planted at Henderson Elementary and approximately 350 at the other school would have to be secured. Both sites would also have to be prepared. In total the final level of support for this tree planting would reach a value of $100,000.00 to provide the resources required to make this project a success. An informational breakfast was held for community and business leaders. Our group of planners also held and attended other gatherings to present the project. In the months before the planned mass planting, the equipment and materials were donated to ready the sites by companies such as Monsanto, Chemlawn, St. Charles Quarry, St. Charles Sand, etc. Grants from local organizations such as the Henderson Parent Teacher organization and businesses such as Union Electric Company provided the remainder of the resource base.

The planting was planned for the fall of 1990. Over 1000 individuals were expected for the event. To provide an orderly, enjoyable event that resulted in the proper planting of our new forest we would train over 100 volunteers to supervise the proper planting of the trees. Each volunteer would organize their own planting team. To plant a tree you had to preregister with such a group. The group size was limited to the planting of 10 trees or less.

To share our vision of a revitalized school community and celebrate the beginning development of the Henderson Educational Park, we invited the Young Pioneers organization in the Soviet Union to send a group of children to share in the event. They responded with 11 children plus 4 adults that were able to spend 2 weeks with our school. These two weeks were spent developing friendships, sharing information and studying together.

The excitement in preparing for the tree planting event rivalled any holiday. But as a holiday the day of the planting passed quickly. The event itself was executed with great pomp and circumstance while the trees were planted in approximately an hour and a half. All that remains now are the trees that remind us daily of that event and the continued vision of a place where learning and teaching are exciting and enjoyable. The organization known as the "E" Team (Excellence in Educational Environments) continues to strive to complete the educational park. What we would share with any who would begin a similar project would be this:

1) Look for and use everyone's ideas to add to your project, you will enlist their support as you do and enrich your effort.

2) Do not minimize an objection but work hard to understand and find a solution to the problem, in doing so you will gain the loyalty of those who have raised the issue.

3) Plan great things but plan them carefully, no one wants to be involved with something that is ill planned or mundane.

4) Make sure you start small and build on success, stay within the limitation of your organization but make it stretch to meet a goal, this will bring out the best in everyone

5) Recognize that everyone has their own objectives, make sure you understand these and help them achieve them as you work together on the project.

Of these five items perhaps number 5 is the hardest to explain. When we approached a business or organization for funding or resources we did not first ask them for support but began by trying to learn how we could help them achieve their own goals as a business or organization. For example, Union Electric Company

spends great sums of money in our area trimming trees that are improperly planted under power lines. These pantings are also unsafe. Children can easily come into contact with power lines by climbing such a tree. To meet the needs of our business partner we developed plant identification tags that indicate which tree can safely be planted under utility lines. This met their goal of community education and will ultimately save money and perhaps serious injury or even the life of a child. The tags also contain other information we wanted to present!

People still take time to care for and sometimes plant an additional tree at the Henderson Educational Park. In less than an hour a few people who may have known little of each other before can share in the planting of a tree while they create relationships that help to improve the school community.