PROPAGATION OF CLONAL ROOTSTOCKS BY HARDWOOD CUTTINGS

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There are five main methods of propagating rootstocks: by seed, softwood or hardwood cuttings, root cuttings, mound layering, and tissue culture. Our firm has specialized in the growing of hardwood cuttings since 1955, when Lyle Brooks, my grandfather, retired as co-owner of the Carlton Nursery Co. and began the Daybreak Nursery.

The hardwood cutting method is an excellent way to propagate fruit tree rootstocks such as those for plums, pears, and cherries. It is also an excellent way to propagate certain shade trees such as London planetree *(Plantanus × acerifolia)* and *Prunus × cistena*. There are two times in the year in our area when such hardwood cutting material can be gathered and rooted successfully — the months of November and December (late fall and early winter) and the last half of February and the first half of March (late winter and early spring).

Cutting material should be taken from stock trees that have been in place for at least two years. Material can be taken off younger stock trees but the success rate will be reduced by at least 50%. Material can also be collected from the tops of cutting beds or from one-year budded rootstocks in the nursery but the success rate of this source of material can be as low as 10 to 20%, depending on the time of collection. Such material is often too green and varies drastically from year to year. Mature stock trees that in our climate are watered once in June and once in August are, by far, the best source of cutting material. Maturity in these stock trees will vary from year to year but not as drastically as in the cutting beds or nursery row, as the amount of water they receive over the summer months is minimal, as compared to the great volume of water applied to the cutting beds or nursery row required for vigorous growth before budding. No one calendar date will ever be correct for taking cuttings on a year to year basis.

Stock trees are generally planted on a 2 by 6 ft. spacing. The 6 ft. spacing between rows allows adequate room for tilling and is necessary for good branching. It is also necessary to let in the proper amount of sunlight. Stock trees should be tilled 4 or 5 times a year and the proper sprays applied when required. Healthy stock trees are essential for success in rooting hardwood cuttings.

After the cutting material has been collected it should be made into cuttings by at least the 5th day. If the cutting material begins to dry out the cuttings will not root successfully. Cuttings can be made as short as 6 in. or as long as 24 in. The shorter cuttings seem to do better as the amount of stored energy required to get them started in the spring is not as great as that needed for longer cuttings. Basal cuttings are always more successful than are the 2nd or 3rd cutting on the same branch.

After any side shoots have been trimmed from the main cuttings, they can be tied in bundles of 50 or 100, depending on size, and topped to length. They should then be dipped in a rooting hormone immediately. A fresh cut on the basal end is required for rapid hormone intake. The cuttings should not be dipped in the rooting hormone for any longer than 5 seconds. Also the rooting hormone should be no deeper than ¼ in. There is no advantage, and often a disadvantage in dipping more than just the extreme basal end.

For both spring and fall cuttings, a solution of 2500 ppm indolebutyric (IBA) is used. The solvent consists of 50% grain alcohol and 50% lukewarm water.

Within the hour these treated cuttings should be packed in wooden crates, such as lettuce crates or apple boxes, and sealed with poly-lined kraft paper, wiht at least two inches of semi-moist peat moss placed in the bottom of the box. This peat moss will help maintain humidity in the box for the storage period that follows. No heating cables under the rooting medium are required, nor is it necessary to cool the tops of the cuttings to stop new shoot growth.

After packing, the boxes are then transferred to a temperature controlled room and left for a period of from 9 to 14 days for spring cuttings, and up to 30 days for fall cuttings. Fall cuttings are usually more successful than are spring cuttings. Fall cuttings tend to remain dormant during callusing while spring cuttings will begin to break new shoot growth, which is detrimental when transplanting to the beds. The temperature of the callusing room should be kept at a constant 64°F.

After the cuttings have been properly callused, they should be transferred to cold storage (34° to 36°F) until planting time in the spring. It is not necessary for these cuttings to be rooted at the time of planting; in fact, it is harmful. The rooting should take place in the ground. If possible, planting in our area should begin by April 1st and be completed by May 1st. The ground temperature should be at least 55°F before planting.

Cuttings should be planted in beds as opposed to single row planting to avoid sunburn and excessive loss of moisture. Sawdust or barkdust should be applied over the beds immediately as a moisture and weed controlling agent. The sawdust mulch should be at least 2 in. thick. It most soils it is necessary to punch a hole in the ground for each cutting before planting. The best spacing we have found for our cuttings is 3 in. apart across the bed and 4 in. apart running the length of the bed. Any farther apart and the cuttings will become too large in a single season; any closer together they will not achieve enough growth to bud. The cuttings should be planted to a depth of 6 or 7 in. for best results. The beds should be watered at least every 10 days from the time of planting in the spring to the middle of September.

Hygiene is one of the most important factors for success in making hardwood cuttings. The peat moss used for humidity control in the boxes should not be reused. All tables, walls, and floors in the warehouse should be sterilized with a Clorox solution before use each year. Also all pruning equipment should be sterilized in the same manner before use each day. Mold in the cutting boxes is one of the largest causes for failure. It can spread rapaidly in the callusing room and can kill all the cuttings in a box in a very short time. Immature cuttings particularly are likely to mold in the boxes and great care should be taken to use only mature cutting material.

To help keep mold under control, the cutting material should be dipped in a solution of Captan or Benlate and allowed to dry completely. This process should be done after the side branches have been removed from the main cutting but before the cutting sticks have been tied for sawing. As the cuttings are placed on top of the peat moss in the box for callusing, a 5% Captan powder should be sprinkled lightly over the peat moss to control mold. Also all stock trees should be sprayed in the fall, after leaf fall, with lime and copper sulphate mixed at the rate of 10 to 12 pounds of each to 100 gallons of water. This will also help control mold during the longer winter storage.

When the cutting material is removed from the stock trees, it should be placed in a clean wheelbarrow or placed on a tarp so as not to come in contact with the soil. Also the truck or trailer used to haul the cutting material to the warehouse should be lined with a clean tarp. Every effort should be taken to keep the cuttings as sanitary as possible. Success depends on strict compliance with these procedures.

Determining the correct time to take cuttings is the single most elusive aspect of our nursery work. What does well one

year may fail the following year. As the stock trees get older, the timing changes by several weeks. The amount of rainfall over the summer; the amount of sunny versus shady days; and the temperature all have a varying influence. In our locality it is best not to take cuttings until after the first major frost in the fall. Excellent records must be kept of all pertinent data and any changes in scheduling or procedures should be noted.

SOFTWOOD CUTTING PROPAGATION OF CERTAIN SHADE TREE SPECIES

LANCE LYON

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Softwood cutting propagation of deciduous trees is relatively new to the nursery industry. In the past most tree cultivars were produced by budding or grafting. This is still the most common method of propagation for most cultivars. However, this has created some problems. Notably delayed incompatibility in certain red maples. To circumvent this problem it has been necessary to find other methods of propagation. In 1976 Femrite Nursery began to experiment with rooting red maple softwood cuttings. This was done by placing the prepared cuttings in a flat for rooting under mist. The resultant rooting was adequate, but we lost many of our cuttings when we transplanted them to pots for overwintering. We began to look for some method to root the cuttings without having to transplant them.

After much trial and some error we have developed a method of propagation which works well for us. We now use a McConkey pot which is 2¼ in. square by 5 in. deep. We can put 49 of these in a 17 in. square mesh bottom flat. The flats are filled with pots and the pots are filled with a medium of 60% horticultural grade perlite and 40% aged sawdust. This medium gives good drainage while insuring adequate water holding capacity. The flats are then placed on the benches under mist.

The cuttings are taken, beginning in early July, from the stock garden or field stock. They are plunged in water immediately upon cutting to maintain their turgor. The cuttings are then brought into the warehouse where they are kept cool and damp until they are prepared for sticking. We make the cuttings 6 to 10 in. long depending on the cultivar and amount of scion wood available. One or two leaves are left on the cutting

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and the base is cut flat and wounded on both sides. The prepared cuttings are then taken to the greenhouse, treated with a rooting hormone, and stuck in the prepunched pots.

The cuttings are taken during the hot part of the summer and are placed on unheated benches where they are misted as often as necessary to insure they do not dry out. They usually callus and begin to root in 10 to 14 days. The speed of rooting depends on the cultivar and, to some extent, the maturity of the wood. Most of the maple cultivars root quite rapidly while the cherries and plums callus fast but root more slowly. We are rooting cultivars of red maple (*Acer rubrum* 'October Glory', 'Armstrong', 'Karpick', and 'Northwoods'); plum (*Prunus* × blireiana, *P.* × *cistena*, and *P. cerasifera* 'Newport', 'Thundercloud', and 'Vesuvius'); flowering cherry (*Prunus serrulata* 'Kwanzan' and 'Mount Fuji', *Prunus subhirtella* 'Pendula Plena Rosea'); and *Betula nigra* 'Heritage'. We expect an 80%, or higher, rooting on all of the cultivars except the 'Heritage' birch which does not root well. (We are also trying several other new cultivars this year, but do not have the results yet).

The rooting percentages are high enough to warrant rooting the cuttings directly in individual pots. As the season progresses we go through the flats culling out any dead cuttings and consolidating them. In late fall the cutting flats are transferred into poly houses where they are held through the winter. In the spring they are removed from the houses and planted in the field along with our seedlings. We have built a single row planter to handle the potted cuttings. The square shape of the pot forces the roots to move up or down in the pot rather than wrapping around it. Once planted the roots move out into the soil in a normal manner, giving us the type of root formation we are accustomed to. Once planted the cuttings are treated in the same manner as the budded seedlings.

Softwood cutting propagation has allowed us to increase our production of shade tree cultivars, (which grow as as well from cuttings as they do from budded seedlings) but have the advantage of being on their own roots. We are continually trying new cultivars by direct sticking. We feel that the only reason not to produce plants in this manner is if they do not root in high enough percentages to make it profitable. We are pleased with our success but we are continually striving to improve our timing and methods to increase productivity.

STOOL BED PRODUCTION OF CLONAL APPLE UNDERSTOCKS

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The production of clonal apple understocks in stool beds is dependent on the process known as mound layering, hence the terms, "stool beds" and "layer beds", are frequently used interchangeably. In layering, the exclusion of light and provision of a suitable environment favors root initiation and development on a developing shoot while it is still dependent on the mother plant for nutrition. In stool beds this is accomplished by surrounding the bases of growing shoots with moist sawdust, inducing the process of blanching.

The reasons for propagating apple understocks through this process are: 1) difficulty of other means of production (hardwood or softwood cuttings); 2) its adaptability to mechanization; 3) high quality of the liner produced; 4) relative low cost of production; and 5) ease of maintenance and inclusion into the work calendar.

Understocks currently in production at Carlton Nursery include Malling-Merton 106 and 111 (MM106 and MM111) and East Malling 7A and 26 (EM 7A and EM 26). The words Malling, Merton, and East Malling refer to the locations of research stations in England that have worked together to develop the understocks. In recent years clonal understocks bearing the designation, EMLA (**E**ast **M**alling-**L**ong **A**shton), have become available, indicating selections which have undergone heat treatment and virus indexing and can be sold or used as virus-certified when grown according to the requirements of the certification program governed by the state in which they are grown. Virus-certified clonal apple understock are also being developed through other programs, such as the USDA IR-2, in the United States.

Briefly, MM 111 can be described as a semi-vigorous rootstock, MM 106 and EM 7A as semi-dwarfing, and EM 26 as a dwarfing apple rootstock. For more detailed information on these and other rootstocks, consult references 1, 5, and 7.

Planting and Establishment. A well drained soil of good fertility is a requirement for longevity of the stool bed. It should be as level as possible and rock free. The site should be prepared and fumigated in accordance with state requirements if it is to be used for production of virus certified understock. The chief purpose of fumigation is to reduce (hopefully to

eliminate) the presence of viruliferous nematodes which are capable of transmitting viruses from a host plant to an uninfected plant.

In the spring, understocks are planted in rows 4 to 6 ft. apart (at Carlton Nursery the rows are spaced 6 ft.) and 6 in. apart in the row. The rows should be oriented north-south; east-west-oriented rows have a tendency for the sawdust to dry out on the south side (2). It is very important to use high quality, large caliper liners, as it has been shown that yield is affected by the quality and size of the original plant (8).

The understocks are allowed to grow for one year, whereupon early in the spring and the following year they are cut back to 1 in. above the soil level and the mounding process is begun.

An alternative means of establishment is to plant the understocks 9 in. apart on a 30 to 45° slant, then grown for 1 year. They are then pinned down using twine and hop clips pressed into the soil, and then the mounding process is begun.

The first year's production is very light; full production is not realized until the 4th to 6th year. The life of a well maintained stool can easily exceed 20 years (4,7).

Table 1 gives graded harvest specifications for the Carlton Nursery stool beds in their 4th year of production.

Table 1. Graded rootstock production in the fourth year's production.

Rootstock clone	Yield of No. 1 Quality Rootstocks	Acreage	Yield liners/acre
MM 111	73,560	2.35	31,302
EM 7A	70,350	1.86	37,822
MM 106	21,900	1.45	15,103
EM 26	16,100	1.86	8,656

From this table some patterns are evident, although they must not be taken as exact characteristics. MM 111 and EM 7A both produce very prolifically in the stool beds. MM 106 is not as productive, yet it should provide a much higher yield than we have received. EM 26 is the poorest producer, a noted characteristics of this clone (5); it also yields a greater proportion of shoots with bent stems, which are discarded. However, it also should be considerably more prolific than is seen here. Both EM 106 and EM 26 have suffered due to areas of poor drainage, resulting in poor establishment in our stool beds.

Production Procedures. For the sake of simplicity we will consider the work schedule through one calendar year.

January: Harvest of layers from the stool beds is generally accomplished in January, but may be done any time from leaf drop to early March. Cool, cloudy weather is ideal; sub-freezing weather should be avoided.

The rootstocks are first undercut by means of a tractor-drawn sickle mower which is adjusted to cut just above the mother plants. It is important to cut as low as possible so that the mother plant does not become too tall or uneven in time. However, by cutting too low it is possible to destroy the mother plants; hence it is necessary to frequently check the cutting depth.

The layers are shaken to remove excess sawdust, stacked, and tied then moved to cold storage to await grading.

The sawdust is left in place over the mother plants for protection from sunburn and cold temperatures until March.

February: No work required.

March: The stool beds are swept with a converted street sweeping brush mounted on a tractor. Following this they are hand raked to remove residual sawdust and any remaining shoots are cut off and discarded. At this time the only fertilizer application of the season is done, consisting of 300 lbs/A of ammonium nitrate (34-0-0).

April: In the latter part of the month frequent checks for leafroller and leaf-tier damage are begun. Damage to the terminals from these pests can easily ruin an understock at this young age. Sprays of Guthion, Orthene, or Diazinon have provided effective control. By the first of the month growth should be in the range of 4 to 6 in.

May: Leafroller sprays as necessary. Growth should be 12 in. by the first of the month.

June: Fresh sawdust is applied using a specially constructed tractor-drawn spreader which deposits sawdust on both sides of each row. This sawdust is packed into and against the layers by hand, taking care to see that the new shoots are as straight as possible. The sawdust should be applied no higher than 8 to 10 in. above the base of the shoots; if applied too high burr knots may form which will be very unsightly if exposed on a finished tree.

Irrigation commences soon after sawdust application, the first irrigation being very heavy to insure that the sawdust is thoroughly wetted. High moisture levels are necessary for good rooting and must be maintained through the growing season.

Leafroller sprays are applied as necessary. Growth should be 18 in. by the first of June.

July: Irrigate to maintain good moisture levels in sawdust. Sprays for mites may be necessary. Growth should be 24 to 28 in. by the first of the month.

August: Irrigate to maintain moisture levels. Most cultivars will begin to show roots this month. Mites and aphids may require spraying. Plants should be checked frequently for woolly aphid, especially toward the base of the shoots. This pest causes serious deformation of the shoots and is difficult to control as it thrives in the environment within the sawdust. Temik or Di-Syston have both shown promise as effective controls. Care should be exercised in their use as they are extremely toxic. Growth should be 32 to 36 in. by the first of August.

September: Irrigate to maintain sawdust moisture levels. This month through the end of October is the period of greatest root development.

Growth should be 36 to 38 in. by the first of the month.

October: Irrigate as needed. Growth should be 38 to 40 in. by the first of the month and hardening off begins.

November: As leaf drop begins spray with Kocide 101 (6 to 8 lbs/A) as a general fungicide.

December: Harvesting may commence following leaf drop.

Grading. The bundles of recently harvested understocks are brought into the processing room where they are sorted according to caliper and the culls discarded. Layers with crooked stems, lacking good root development, or being too large or small are considered culls. At this time any spurs or side branches are removed, and the roots are trimmed to approximately ½ in., and the rootstocks are topped to a uniform height: 18 in. for MM 111, MM 106, EM 26, and 20 in. for EM 7A. This height is regulated by the desired budding height. They are then tied in bundles of 50 or 100 and again placed in cold storage until planting time.

For further information on stool bed production of clonal apple understocks see references 2,3,5,6 and 7.

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VOICE: Doug Sabin, what is the age of your stock plants when they are discarded as a source of hardwood cuttings?

DOUG SABIN: We have some old as 20 years. But the age at the beginning is more important. Cuttings do not root well until the stock plants are at least 3 years old.

VOICE: Why is *Prunus bessyii* not used more as a dwarfing *Prunus* rootstock?

DOUG SABIN: There is a considerable incompatibility problem with many *Prunus* cultivars worked on *P. besseyii* roots. But I don't know the reason for the incompatibility.

ALAN ELLIOTT: We have used *P. besseyii* as a rootstock. It is grown from seed and there is pronounced seedling variation in regard to its incompatibility reaction. For example, in a block of a peach cultivar worked on *P. besseyii* seedling roots you can see the great variation in tree growth due to the incompatibility encountered with some roots, but not others.

ED SCHULTZ: In storing your hardwood cuttings through the winter — are they upright or horizontal?

DOUG SABIN: The 10-inch cuttings are packed upright in peat moss in 14-inch high poly-lined boxes with air space at the top.

BEVERLY GREENWELL: How does the growth of *Acer palmatum* started from softwood cuttings compare with that from grafted plants.

LANCE LYONS: The rate of growth is better than the grafted plants.

VOICE: Is there a special procedure you use to overwinter your liners from softwood cuttings?

LANCE LYONS: After rooting, they go out into a poly house for the winter without heat, then brought out in the spring for planting in the field.

VOICE: Would you define Myro 29C?

DOUG SABIN: It is a selected seedling of Myrobalan plum — *Prunus cerasifera* — which has been maintained as a clone and used as a clonal, vegetatively propagated, rootstock. It was probably originally selected for its vigor and ease of propagation by hardwood cuttings.

VOICE: What is a good control for mildew on sugar maple seedlings?

DON POND: We use Captan-Benlate sprays.

MICROPROPAGATION OF DECIDUOUS TREES

GAYLE R. L. SUTTLE

Microplant Nurseries, Inc.
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Microplant Nurseries was established in 1980, with our first crop going to the field in the spring of 1981. We have specialized in the micropropagation of new and improved fruit tree rootstocks of apple, pear, plum, and cherry, as well as self-rooted ornamental and shade trees such as flowering plum, flowering crabapple, birch, and Norway maples. We presently have 26 cultivars in production. These are produced in quantities of 5,000 or more per year. An additional 42 subjects are in various stages of research. Such items as red maple, sugar maple, ornamental pear, filbert, apple, and cherry cultivars are all part of our research program.

Our facility consists of a 1600 sq. ft. building divided into 4 separate areas: an outer office and storage area; a media preparation room complete with an autoclave, water purification system, pH meter, weighing machines and dishwasher; a transfer room with three laminar flow hoods, where all sterile sub-culturing takes place; and a culture room with 1,024 sq. ft. of shelf area. The culture room is maintained at 25°C with a 16-hour photoperiod.

There are three *in vitro* stages of growth in the micropropagation process: culture initiation, multiplication, and rooting. Each stage requires a different medium formulation. We have found that there are differences in nutrient requirements almost on a cultivar by cultivar basis, so that we now start with Murashige and Skoog's (MS) basic formula (1) and make systematic changes as needed. While much work has been done in the past on changing the type and concentration of plant growth regulators, we have found that the inorganic salts also play an extremely important role in promoting or inhibiting

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optimal culture growth. For example, we have found that *Acer platanoides* 'Crimson Sentry' requires roughly 3 times as much phosphate as MS recommends, while needing only ½ the sulfate level during Stage II. The result of these changes has been a 3-fold increase in multiplication rate and better rooting as well.

THE PROCESS

Stage I: Culture Initiation. Cuttings are sterilized to rid them of bacteria and fungi and then planted on a sterile nutriet medium. Then the plant must grow or "activate" in culture. While we have successfully started cultures during all seasons of the year by taking dormant buds in the fall and winter and tiny softwood cuttings in spring and summer, we have had the best results with softwood cuttings taken during early spring. The young shoot tips are cut 2 to 5 cm long and, after the larger leaves are removed, the tips are placed in a solution of 10% household bleach, plus a pinch of surfactant, for 10 min. The tips are then rinsed once in sterile water and placed on ½-strength MS medium, with no growth regulators, and allowed to incubate for 10 days. If the shoot tips are clean and active after this period of time, the material is transferred to fresh Stage II medium.

Proper stock plant care greatly improves our success during Stage I. We select the healthiest, youngest, cleanest stock available and maintain it in the greenhouse using an intense pesticide and fertilization program along with bottom watering. We also prune the stock trees frequently.

Stage II. Multiplication. By adjusting plant growth regulators and nutrients in the medium we can promote axillary branching. The branches are harvested every 10 to 21 days and planted into a fresh Stage II medium which, in turn, allows these new shoots to branch. This step is repeated every 2 to 3 weeks until a sufficient quantity of shoots are generated to satisfy our needs. Timing is critical during Stage II as it is important to catch the cultures when they are at the peak of the growth cycle. A delay of 5 to 10 days results in reduced yields and a lower multiplication rate during the next cycle.

Stage III: Rooting. There are two ways of rooting Stage II plantlets: 1) ripe shoots 1 to 3 cm tall may be rooted *in vitro* in media with reduced salts and no cytokinin, or 2) the microcuttings may be rooted directly into a potting mix under greenhouse conditions. The finished product at Microplant is either the rooted plantlet, or the microcutting.

Often we find ourselves working with plant materials which are difficult to root by conventional methods. If our

standard formulation of ½ strength MS medium, with 0.2 ppm indole-3-butyric acid (IBA) does not promote roots, we look at a number of factors such as auxin type and concentration, timing, brand of agar, the salt level and composition during Stages II and III, carbon to nitrogen ratio, etiolation, or additives such as charcoal, ancymidol, vitamins, and phenolic compounds.

GREENHOUSE ACCLIMATIZATION

The rooted plantlets or microcuttings must be placed under a high humidity environment in the greenhouse for several days and then the humidity is gradually lowered as the plants become adjusted to the greenhouse atmosphere. It takes 6 to 12 weeks of greenhouse growing for the plants to reach the 15 cm height desired for field planting. Most of our material is field-planted in the same season it is brought out of culture. Material that is brought out in late summer is either fall-planted or held over until the following spring.

COLD STORAGE

While it is possible to produce micropropagated material on a year around basis, the high cost of heating and lighting greenhouses during the winter months of October through February has led us to the use of cold storage during these months. The rooted plantlets, still in sterile containers, are placed under refrigeration at 2°C and total darkness. We are able to store material in this manner for up to 6 months without significant losses. We also use cold storage to maintain stock cultures of items that are produced on a seasonal basis. We can maintain material indefinitely this way if subcultured at least once a year. This greatly aids in smoothing out our production peaks, allows much more efficient use of personnel, equipment and, most important, allows the grower much more flexibility as to when to plant in the greenhouse.

Another important lesson we have learned is that many deciduous trees have a chilling requirement which must be satisfied in culture in order to achieve optimum growth. We have seen a remarkable increase in greenhouse growth when *Pyrus communis* 'Old Home × Farmingdale #333' Stage III plantlets are given a chilling treatment prior to greenhouse planting. We have also seen this in several crabapple and apple selections, but not in any of the *Prunus* species. We are now pre-chilling all material 1000 hours as a standard practice prior to greenhouse planting.

THE FUTURE

Every propagator has at least one plant — be it a shrub, a perennial, or a tree — that they wish they had more of. Perhaps it is a new cultivar, or a plant that does not root well, or maybe it would be advantageous to get the plant on its own roots to avoid graft incompatibility or low bud stands. These are the types of situations where micropropagation can and will be a big benefit to the industry. In the short time that micropropagation has been applied to deciduous trees, much progress has been made on developing formulations for new plants and streamlining the process to make it economically competitive. It is a tool which all propagators should consider as part of their arsenal when considering their propagation options.

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VOICE: Gayle, what is the sterilizing solution you use in preparing your birch explants?

GAYLE SUTTLE: We use 10% Clorox household bleach plus a surfactant, such as Tween 20, for 5 to 20 minutes.

RANDY BURR: On your direct stick micro-cutting birch are you coming right from the multiplication medium or do you use a rooting medium also?

GAYLE SUTTLE: We come straight from the multiplication medium for the cutleaf birch.

RANDY BURR: Have you found any seasonal differences when you bring the materials out?

GAYLE SUTTLE: Yes, the best time to bring the micro-cuttings out in the Oregon climate is in March-April so as to fit in with the growing season, so we use cold storage quite a bit.

VOICE: Dr. Anderson, what components are is your rooting medium?

WILBUR ANDERSON: We use ½ strength inorganics, drop out the cytokinins, and use 0.5 mg/liter indoleacetic acid.

LES CLAY: This for Gayle Suttle. When there is a callus at the base of your sub-cultures do you or do you not throw them away?

GAYLE SUTTLE: There is no set time that we sub-culture. If there is a lot of callus build-up we want to get rid of it for two reasons: for genetic stability — and lots of callus means that the clump is over the hill anyway.

DUPLEX GRAFTING OF HEMLOCKS

RICHARD BUSH

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Duplex grafting is a technique for avoiding possible delayed incompatibility in those cultivars classed as shy rooters from cuttings. A duplex graft is essentially using a nurse root provided by the understock. An approach graft is made in the normal manner on an understock established in a 4-in. pot. The first difference occurs when we tie with an .016 × ¼ × 4-in. long budding rubber and put the slip knot on top, spacing the wraps very open, about equal distance untied area to tied area.

In the next step, we use a small ½ in. wide camel hair brush to apply an auxin over the entire cut areas. We use Wood's Rooting Compound ⅒ strength, which is 5,000 ppm IBA and 2,500 ppm IAA. Now a "Twistem" is securely tied just below the base of the cut (this will girdle the rootstock as it grows). "Twistems" are small steel wires covered with paper.

Next, we transplant the rootstock into a pot 3 in. taller but with the same base dimensions as the above described pot. The top of this pot is filled with perlite or other rooting medium to the top of the bud strip which hangs out. When this method is used in summer we place the grafts under intermittent mist. When done in spring or fall, the grafts are placed in cold frames and, in winter, they are put in the greenhouse. The rootstock top should be removed in stages, as in any other method.

At the end of the first year the slip knot on the budding rubber is pulled and it is snaked out. Three or four months later the plant is transplanted into a 1-gal. container. At this time one will note that the rootstock is completely girdled by the "Twistem." If one is concerned by the new roots initiated by the rootstock above the "Twistem" they can be removed at this time, leaving the cultivar hemlock totally on its own roots.

PROPAGATION OF FILBERT TREES BY LAYERING AND BY GRAFTING

VERL L. HOLDEN

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The introduction of new cultivars of filbert (*Corylus avellana*) for the production of hazelnuts in Oregon has sparked new interest in planting more orchards, thus creating a demand for more trees of the newer cultivars. *Corylus avellana*, having been in cultivation for the last 4,500 years, is easy to propagate by seed, or from selected cultivars by layering but the latter process is lengthy and laborious.

The most primitive method of propagating a desirable cultivar is simple division. *Corylus avellana* is prone to produce shoots from the base of the tree or root crown. These shoots, commonly called suckers, sometimes arise from below ground level and root naturally. The naturally rooted sucker is then simply cut from the mother tree and planted in the desired location.

PROPAGATION OF FILBERT TREES BY SIMPLE LAYERING

The commercial production of filbert trees in the Willamette Valley of Oregon is now accomplished by simple layering. A layer bed is established by planting cultivars on their own roots. When the plant is well established after 2 to 3 years the top is cut off near ground level, forcing the plant to send up a cluster of suckers. These suckers may then be bent down into the ground and out again leaving 12 in. or more sticking out of the ground to continue growing.

Roots will form where the stem is in contact with moist, well aerated soil. The layering process is best done in early spring when the buds are just beginning to swell. The shoots are quite supple and easily bent with a minimum of breakage. A trench 4 to 5 in. wide and about 6 in. deep is dug close to the clump of water shoots. Then, moving backwards on hands and knees, each shoot is bent into the trench and back out again. Soil is then back filled into the trench and tamped into palce to keep the shoots from whipping back out of the ground. Still being attached to the mother clump, the new layers will sometimes reach 6 ft. in height in a single season. The tops have to be reduced considerably when planting in order to balance the small root system on the layer. Simple layering is expensive, uses a lot of land, and does not lend itself to mechanization or cultivar change very easily. Introducing a new cultivar is a slow tedious process.

PROPAGATION OF FILBERT TREES BY MACHINE WEDGE GRAFTING

Filbert trees can now be grafted successfully by using the hot callus treatment (2,3). I am using the Heitz Grafting Tool to make a fast, easy precision wedge graft (1). The desired cultivar is grafted onto 1-0 seedlings with a caliper ranging from ¼ to ⅝ in. Scionwood of any cultivar can be taken from orchard trees rather than wait for a layer bed to be established. Thus a new cultivar with limited scionwood can be brought into production quickly.

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HOT-CALLUS GRAFTING OF FILBERT TREES

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Silverton, Oregon 97381

The hot-callusing pipe, a grafting aid (1), was first introduced by Dr. H.B. Lagerstedt, U.S. Dept. of Agriculture, Agricultural Research Service, Corvallis, Oregon at the 1981 IPPS Western Region meeting in Vancouver, British Columbia, Canada (2). The first hot-callus pipe was a 2 in. PVC pipe with slots cut in it. Inside the 2 in. pipe, is a ½ in. liquid-filled PVC pipe with heating cables taped onto both sides to maintain 80°F in the hot-callusing pipe.

In August 1981 the first large scale hot callusing pipe was constructed with 1,200 feet of 2 in. PVC pipe and 9,600 ½ in. and ⅝ in. slots cut perpendicular to the pipe. Three slots were cut at one time by clamping three pipes together, and with the use of a radial arm saw containing a variable width dato blade, the slots were uniformly notched.

The heat source for this system is circulating hot water through a ½ in. PVC pipe inside the 2 in. slotted pipe. This is accomplished by using a closed system consisting of a residential 40-gallon gas water heater, ¼ H.P. 1,725 RPM electric circulating pump and a 20-gal. expansion tank placed 6 ft.

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above the pump. A 2 in. manifold is used to distribute the hot water to the ½ in. lines inside the slotted 2 in. pipe. This system performs best at 20 to 30 PSI at the pump. The pump is placed on the cool side of the water heater and pushes water through the heater. Temperatures at the heater are 79° to 80°F, going in from the pump, and 81° to 82° F going out to the hot-callus pipe; the temperature is controlled only by the thermostat on the hot water heater. This system has very little heat loss or temperature fluctuation and it operates on less than 2 gallons of propane per day, which makes it far more economical to operate than using electric heating cables.

To attain this efficiency, we placed the complete hot-callus system on redwood furring strips with 1 x 2 in. styrafoam glued to the strips. We then nailed the 2 in. slotted pipe on top. To stop heat loss through the top, a ⅛ in. closed cell foam and a layer of 6 mil black polyethylene was placed over the 2 in. pipe and stapled on each side of the furring strips. A single knife cut was made in the center of each slot in the pipe. We not only benefited from excellent insulation provided by the foam and black poly, but acquired a serviceable means of holding our grafts in the pipe.

With the use of sawdust between the pipes to cover the bare roots, grafted stock is easily and quickly added and removed from the hot-callus pipe. Root moisture is maintained by overhead irrigation of about 5 min. per day.

An unheated fiberglass greenhouse with a concrete floor housed our system. The greenhouse temperatures inside were kept as close to outside as possible except when freezing. After 2 seasons, we feel the best place for a hot-callus pipe system is out-of-doors where the lower temperatures will hold back otherwise premature bud break.

Complete knitting of some *Corylus avellana* cultivar grafts has been obtained in 14 days on seedling rootstocks, but the grafts are usually all left on the hot-callus pipe for 21 days.

Other genera that we have successfully grafted with the aid of the hot-callus pipe are: *Acer*, *Cedrus*, *Cercidiphyllum*, *Fagus*, *Malus*, *Prunus*, and *Sequoia*.

The 80°F temperature is too high for spruce and seems to inhibit healing of the graft union. Temperature in this range on spruce also seems to cause fungus growth between the scion and the understock.

We need much more research in order to establish temperature and cultivar combinations so that the hot-callus pipe may be an even bigger aid than it is already. The future in this field is unlimited.

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WINTER GRAFTING OF CEDAR, SPRUCE, AND ORNAMENTAL CHERRY

LANCE LYON

Femrite Nursery Company
13193 Arndt Road N.E.
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At Femrite Nursery we graft cedar and spruce in the greenhouse, and cherries in the field.

Production of the grafted conifers begins with the harvesting of the seedling understock. The roots are trimmed and they are potted into 4 in. pots. This is done a year before the grafting is to take place. The understock is left outside until late October and then it is brought into the greenhouse and prepared for grafting.

By December the understock is producing new roots and the scionwood is dormant and is ready to be taken for grafting. We use a side veneer graft for both the cedar and the spruce. First the cuts are made and one edge of the scion is matched to the understock. Then the graft is wrapped with a budding rubber to hold the scion in place and the sides are painted with Tree Heal. The grafts are then placed back on the bench and covered with poly to keep the humidity high until the graft union has time to heal. After about two weeks the poly is removed and the grafted plants are maintained until late spring. At that time the grafts are moved out into shade houses until fall when they are planted in the field.

The Atlas cedar cultivars we graft are *Cedrus atlantica* 'Glauca,' *C. atlantica* 'Glauca Pendula.' Spruce includes *Picea pungens* 'Moerheimii,' *P. pungens* 'Monterey,' and *P. abies* 'Pendula' (weeping Norway spruce). These are generally grown in the field for 4 or 5 years before harvesting.

The ornamental cherries are harvested after a much shorter growing cycle. Mazzard seedlings are planted in the field in April or May, grown through the summer, and some cultivars are budded in September. The following spring the plants are all cut off 6 to 8 in. above the ground. Once the buds begin to grow in the spring a single bud is selected and

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allowed to grow. The cultivar bud is selected on those budded the previous fall. This selected bud growing on a well established root system will give a strong straight standard for grafting in February or March the following year.

We use a whip and tongue graft on the cherries. The understock is cut and the backcut made, then the scion is cut in the same manner and the scion is pushed into place on the understock. The graft union is then covered with masking tape and painted with Tree Heal.

At the end of the first growing season we have a salable tree. The standards that grow to 5½ ft. or larger are grafted with *Prunus subhirtella* 'Pendula Plena Rosea' (weeping double rosebud cherry). The shorter standards are grafted at 42 in. to an upright growing cultivar. We also graft any of our budded trees in which the bud did not take. These are grafted at 42 in. except for some of the *Prunus serrulata* 'Kwanzan' (Kwanzan cherry) which are grafted high for street tree use. We expect to get 3 to 4 ft. of growth on our grafts the first year and we usually sell the trees the winter after grafting.

Winter grafting of conifers is the most common method of propagating those special cultivars which do not reproduce true from seed. The ornamental cherries are winter-grafted to get the weeping cultivars up on a high standard and to pick up the misses from budding.

VOICE: This is for Lance Lyons. What time of year do you do your grafting of cedar and spruce and, over the years, what percent take do you get?

LANCE LYONS: We start in December on the spruce, pine, and cedar, and we average over 80% take. On *Acer palmatum* grafts we do not do nearly as well.

VOICE: How large a scion do you use?

LANCE LYONS: For cedar we use an 8 to 10 in. scion. On spruce we use 6 in. — one year growth.

VOICE: Have you had any experience on spruce with smaller scions not wanting to push in the spring?

LANCE LYONS: No, we have not had this problem.

SEED CONE COLLECTION PROCEDURES, SEED EXTRACTION, AND SEED STORAGE

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There are many ways that a commercial cone collector/seed processor can go about collection of seed cones, processing those cones to a finished seed, and placement of the finished seed into freezer storage. Imagine that you are a seed within a cone. The choices that a collector/processor has can make your trip to the freezer, as an inventoried seed, a very short trip with few stops, or a very long trip with numerous stops. As an example, one could determine that a cone and the seed therein is now ripe and collection procedures should begin. The cone picker or pickers could be recruited to go to the field to pick these cones at maturity. Immediately after picking these cones could be transported to the processing plant, at which time they could be trayed up on drying tunnel trays and put into kiln dry at the dryer facility at a high temperature to open the cones. Conceivably, within 24 to 36 hours after a cone is picked, either by tree climbing, or by picking a squirrel's cut cone off the ground, the cone could have been artificially opened and ready to proceed with extraction. After the cones are dried, they are put into a big round tumbler and are thrashed to release the seed from within the cone. The seed then goes through a series of processing machines — a dewinger, clipper, scalper, and air separator. Here then, is a short trip for you, if you are the seed, and your trip could conceivably be completed in two days, from within the cone out in the woods, to within the bag placed in freezer storage.

We, at Brown Seed Company, go through considerably more detail than this and I would like to explain, in this short time, everything that is involved with proper cone collections as we see it — cone storage, seed processing, and freezer storage control. Early in the calendar year, one can determine if there is *not* going to be a cone crop by means of observing very few female buds on the tree branches. After observing many female cone buds early in the year on the tree branches, however, we still cannot be positive that there will be a good cone crop. There may be poor pollination or, after pollination, cold freezing spells that will kill or injure the freshly pollinated seed. There may be infestation with insects, midge worms, etc. So even as early as January, if the cones look as though

there is a potential crop, these other negative factors could totally eliminate any collection possibilities.

With the Douglas-fir *(Pseudotsuga menziesii)* in mind, we make it a practice not even to begin initial cone surveys until June of any given year. By June, pollination will have occurred, freezing will no longer be a factor, cones are noticeably visible and of significant size; however, insect damage can still occur. If, in June, we see most all trees with a number of cones, insect damage will probably not be significantly detrimental to our collections. If, however, as in 1983, you see a few trees with a few cones, or one stand with a lot of cones, or little pockets, as we call them, with a lot of cones, the insects, between June and collection date (beginning in September), could totally devastate any cones on those trees. Firstly, if cone abundance does appear on the trees, people in the industry are aware of that at an early date — June and July, and they are preparing to make their upcoming seed needs known. Some plan to add to their inventory additional quantities of seed so that they have in their hands a supply for one, five, or ten years down the road, seeds they know they are going to be needing. This is a very good insurance or back up for those years when there are no cones.

Nearly all seeds, or all cones, in Washington and Oregon are collected in bulk collections by seed zones and elevation. Each of these states has prepared seed zone maps. These seed zone maps indicate major geographic and/or drainage divisions and are numbered separately, appearing somewhat like county boundaries on a state map. Additionally, each of these seed zones are separated at collection time and through processing, by 500 foot elevational increments. So it is conceivable, just on the seed zone and elevation, to have several hundred seed lots for one given species. We seem to be going now, more and more, to specific site collection within a seed zone, a particular stand that is in demand, usually because of the color of the trees, or the growth rate, or number of branches per whorl. Desirable characteristics for timber related industries are much different than those for ornamental related industries.

In any event, June through August, when our customers realize there is a cone potential, they should contact us prior to the commencement of our collections, to advise us of their needs, their desires of seed zone and origin, and quantities that they want. After determining the seed needs of our customers, studying the cycles of the past years, seeing how good the current year is, determining our own inventory, predicting what the cone situation might be next year or the following year, or even 3 and 4 years in the future, we determine our

demands based on advance orders and speculation for inventory purposes. We know fairly well by mid-July where the potential harvest areas are located. We have driven thousands and thousands of miles, we have entered many, many different areas, and we know what the potential is. We are primarily doing our scouting or field investigations in areas that are historically popular, both for the forest industry and for the ornamental industry. We know our harvest potentials and we have received advance orders by mid-August.

With harvest potential and with seed needs in mind, we are then able to pinpoint the specific stands of interest to us or the specific seed zones and elevations where we want to make our collections. It is now time to further plan and to locate a buying agent in these particular areas. Our buying agents are generally a husband and wife team with repeated years of service to our firm. They have available space within their own residential premises for cone storage once the pickers bring the cones in and prior to our transporting these cones to our seed processing plant in Vancouver, Washington. Once we have determined who our buyer/agents are going to be for our various picking areas, we then notify the prospective certifying agency in Washington or Oregon letting them know of our intent, of our predicted collection by volume, the areas where we will be collecting, etc.

The certification personnel, once collections have begun, periodically make field surveys in the areas where we have indicated we will be picking cones. They check the various areas to ascertain whether our registered cone pickers are picking cones where they had previously stated they would be picking, etc.

Once we have determined all of the above factors and have notified the certification authorities, then it is simply a matter of waiting until the cones are mature and ready to pick. In the meantime, we have sent to our commissioned buying agents the equipment needed for the cleaning, sacking, tagging and racking of the cones. But the big, big factor involved with proper beginning date for the cone harvest is the maturity of the cone and the seed contained therein! Is the cone ready? Is the seed mature? This is the first and most important priority regarding the cone collection. Seed maturity! It is ever so critical that the seed of the cone be mature. Immaturely picked cones with an immature seed can cause losses in many, many ways. We know from experience the approximate date that cones are ready for harvest. Douglas-fir, as a rule is September 1st. This can vary, of course, from mid-August to possibly mid-October, depending on the area of collection, the elevation, the weather pattern to date, etc. It is ever so important

that the cone and seed therein be mature. The best method we have for making sure that the cone and the seed is ready is by inspection of a longitudinal cut of the cone. The cone knife that we employ for this purpose holds the cone in such a manner that when the cutting blade comes down on the cone it is cut longitudinally through the axis. Immediately after cutting the cone, the cut face should be brown, there should be distinct outlines of the seed between each of the scales. By splitting the cone apart, the seed wing itself should be light brown to a deep tan. The dark side of the seed coat should be brown to dark brown. When an immature cone is cut, for instance one that may be sampled in July or early August, the cut face of the cone is totally white and will begin oxidizing, as a green apple will do when cut into. One cannot even distinguish seeds from the scales until after the face of that cone begins oxidizing, which it will do rapidly upon exposure to the air after being cut. Ater exposure to the air, the entire face of the cut cone darkens, then you can see the distinction between the scales and the seed. But for the seed itself, the "endosperm" within that seed is still mushy and milky and the embryo is still small. On the other hand, in a mature cone, after cutting, the face is already brown and the seed coat is brown, and within the seed the "endosperm" is full and firm and the embryo is very noticeable.

The embryo will be at least ¾ the length of the seed and all you see, when bending the cone back, is brown on the wing and brown on the seed coat. It is ready to pick! A problem can occur, however, if one waits too long, and this does happen. On a given day, on a given week of a month, from mid-to late-August the cone is still immature. The full maturity factors are not totally evident, but if it is closely approaching maturity, it only takes a short period of high temperatures and windy days to totally destroy the potential cone harvest. The cones are opened on the trees, the seed is blown and we lose our collection. One very good example of this is in the Columbia Gorge area east of Portland, Oregon. The cones can go from not being ready to pick today, to being open and blown next week.

Once we have determined the cone and seed maturity, the collection can begin. After we have determined the quality of the cone, the seed count, the yield, and the maturity, we begin picking. Our commissioned agents, in the meantime, have recruited (and registered for the certification authorities) cone pickers to harvest the cones for us when we give the go-ahead.

Most often in the areas of Douglas-fir collections, the squirrels do the collecting for us. Quite early, before the cones are even ready, the squirrels sample cones, cut cones and run

down to the ground and open them. They know that the seed is not ready so these early cut cones are something we do not want either. The squirrel doesn't want them so why should we? Later on, approaching maturity and after the cones are mature, the squirrels feverishly cut, cut, cut, cut. The good experienced cone picker can notice trees that have been squirrel cut. He can go the base of these trees and sometimes find numerous bushels under any given tree provided the squirrel has not had a chance, at that point, to cache the cones. The squirrel knows winter is coming, he knows he will need a food supply, his food supply is going to be the seed from the Douglas-fir cone, or whatever cone is in the area where the squirrel lives. Even though the cone picker, cruel as it may seem, takes many of the cones that the squirrel has cut, and robs the squirrels caches, the squirrel has many more caches that are never discovered by even the most experienced cone picker. The squirrel always manages to get through the winter with a big tummy. These cone caches are often found in old, rotten hollow logs, close to moisture. The squirrels are smart enough to know that the cones need to be stored where they are going to stay closed, so hollowed out, moist logs, or by the water in creek beds, etc., are ideal places for these caches to be located.

Once a cone picker fills a sack with cones in the field, immediately upon putting them into his vehicle for transport to the buying station, he should label the sacks. We supply all of our commissioned buying agents with sack tags that are filled out by the picker, indicating seed zone and elevation, species, date picked, certification class, etc., and signed by our collection supervisor. The cones being transported to the station should have tags filled out and attached to, or placed in, the sack of cones.

The cones, which have not been measured in the field, are received at our buying station and dumped out of the sack onto a cone cleaning table. This table is approximately 6 ft. long and 2½ to 3 ft. wide. The top of the table is made up of round dowels that are spaced approximately ⅜ in. apart. The cones are raked over the top of the table allowing all loose debris, leaves, needles, rocks, etc., to fall through the slots. Only good clean cones go down over the end of the table into our one-bushel measuring tub. When we collect, measure, and sack cones at the buy station, we use only one bushel per two-bushel sack. We use a loose weave potato-type sack of burlap.

By placing only one bushel in each sack, and tying each sack at the very top, we have optimum space within that sack for proper air circulation. Air circulation in our operation is ever so important. It prevents heat build up and mold from

forming in and around the cones and the seed. It gives the cone a chance to after-ripen and to begin opening in its natural state, without worry of heat or damage to the seed. Once these cones are measured, an identification tag is placed inside the sack and another tag is filled out and tied to the outside of the sack. Using a dual sack tag method insures that all sacks of cones will be identifiable from start to finish. Oftentimes, the outside sack tag might be ripped loose by handling, or by transporting in any of the phases of our operations. Therefore, the inside sack tag guarantees the identity of that sack of cones.

After the buyer measures, sacks, and tags one bushel of cones per sack, he racks the cones at his buying station. The racks that he uses consist of end supports connected by 2 x 4 wooden rails, on which sacks of cones are placed, allowing complete air circulation in and around each sack of cones. This prevents or reduces the possibility of heat and mold build up. Mold is ever so detrimental to the seed — the finished product. When stratifying the seed, mold comes into play and can have a detrimental effect on the seedling that will grow out of the seed. So we want to prevent this mold.

Prior to the cones being transported to our plant for further storage and processing, a certification inspector goes to our buy station and ascertains that each of these sacks of cones meet certification standards. The sack tags are punched by the certification inspector if these standards are met.

The cones are then removed from the racks at the buying station and placed into our trailer van for transport to our own facilities. Our trailer vans are set up so that we rack the cones while in transit. There is a big screen door on the front of the trailer and, while in transit, air comes through the trailer and filters through all of the sacks of cones and back out through a screened opening in the rear door. Again, this aids in the prevention of heat build up and mold. Once we have the cones delivered to our facilities, the truck is unloaded, and the cones are racked up again. This time, on the racks at our facility, we place big fans in front of the racks of cones to help with air circulation. We do not want, and I emphasize and repeat, we do not want heat build up! We want those cones to dry naturally, with no artificial heat at this point, yet we do want the air to circulate through the cones. We never begin processing a seed lot of Douglas-fir until the cones have been on our racks for no less than 4 weeks and often for 6 to 8 weeks. Some of the last lots that we process in any given year may have been on the racks for 6 months.

When we begin to process Douglas-fir cones, all that have opened to any extent, while on the outdoor racks, are taken to our thrasher for what we call a pre-thrash. All loose seed and seed that is slightly ajar from the scales is extracted from the cones that, so far, have not been dryed in our artificially heated dryer. This seed which is pre-thrashed is separately labelled and sent over to our dryer building with the sacks of cones from which the seed was extracted, each lot again being separately labelled and identified.

After the cones are re-bagged and received at the dryer, the sacks of cones are then placed into big water tanks. We have let the cones after-ripen, we have avoided any mold, have let the cones dry naturally to some degree, but there is still some uneveness of moisture content within any given cone in that sack. Some of the cones in the center of the sack may have a slightly higher moisture content than some of the cones on the outside of the sack. The cones on the outside of the sack are subject to more air or circulation and hence they are dryer, with less moisture. We want an even moisture content on all of the cones that we are beginning to process. This is the reason we soak the cones even though we have already given them a pre-thrash. We soak all cones for 15 to 30 min. prior to being placed in the dryer. Each of the sacks of cones, containing one bushel each, is dumped onto a drying tray. Each drying tray measures about 3 ft. square and about 2½ in. deep. To each drying tray is stapled a seed tag from the cone sack and the wet cones that are on the drying trays are allowed to drip dry before placement into our drying kiln.

After the cones and the pre-thrased seed are placed into our drying kiln and the kiln is filled with cones, we turn on the heat and begin artificial drying, utilizing large fans for air circulation. We know from experience that the cones, as we handle them, are going to be in the dryer for a period of time, usually not less than 24 hours nor more than 36 hours, dependent on the outside temperature and humidity. Approximately 24 hours after being in the dryer, a sample of seed is extracted from these cones. There is a quickie method we use to process a few grams of seed from the cones within the dryer. Once these few grams of seed are processed, we perform a moisture test to determine the percent moisture in the seed. We leave the cones in the dryer, not so much to make the cones continue to open, because the cones are going to be open after 15 to 20 hours, but to reduce the moisture content of the seed in those cones. We want the moisture content of Douglas-fir seed to be no higher than 7½% when we place the finished seed into freezer storage. If we pull the cones from the dryer, with the seed having a moisture content of 6 to 6½%, the small

amount of moisture picked up by the seed in later processing stages will be less than 8% prior to the finished seed being placed into freezer storage.

These cones, once it has been determined that they have been in the dryer long enough, and that the moisture content of the seed is sufficiently low, are brought out of the dryer and thrashed on a lot-by-lot basis. All of the pre-thrashed dried seed, and the thrashed seed from the dried cones, is then delivered to our processing room at the plant for further clean up. The empty cones, primarily Douglas-fir, are ground up and we dispose of this material as a cone mulch, which is similar to bark dust and which is very popular with landscapers.

The seed, once received in the processing room, goes through a number of different machines. The seed is dewinged twice and then sent through a series of other machines — scalpers, clippers, and air separators. Each of these machines is increasing the purity of the seed lot, at the same time, increasing the soundness of the seed lot. Each of the air settings on these various machines is increased ever so slightly as the seed advances to the final processing machine.

Every time we have a seed lot on any of the machines, we are continually cutting the blow out (light-weighted seed) to make sure we are not getting too much good seed in with the light hollow seed to be thrown away. Once the final process has been consumated we do a purity check and a cut test on all seed lots. The cut test, which we have been doing periodically throughout the seed processing stages, determines the number of visible, viable-appearing seed. We call this test a VAS (viable appearing seed) and although we accept a 90% minimum, we are hopeful for a few points higher.

Seed that is filled and appears viable, i.e., seed with a nice firm "endosperm" and an embryo, seed that is not off-colored or dry and shriveled, etc. is considered good seed. We continually check the blow-out throughout these machine processings and determine that we have not lost much good seed with the bad. If the final results, taken on a completed seed lot, indicate that we have almost 100% filled seed, of which 90 to 95% of the filled seed is viable-appearing and purity is 98%, then we are satisfied. Some of the filled seed, no more than 5%, may be filled with a worm or may have a thick seed coat and weigh the same as a fully meated seed, and consequently cannot be removed by air separation.

The finished seed is weighed and labelled and placed into freezer storage for final certification and filling of orders. Our freezer storage temperature is maintained at between 0° and 16°F. We collect additional pounds of seed during a good cone

year for speculative purposes. We know, fairly well, when next year, or the year after, will not be a good year, based on cyclical patterns or what we have observed in the early, early days of crop forecasting. Therefore, from our inventory, we draw seed for a number of years to fill the needs of our customers who have not taken it upon themselves to keep a sufficient inventory for the lean years.

CONIFER SEED SOURCES, TESTING, STRATIFICATION, AND SOWING FOR THE INDUSTRIAL FORESTRY ASSOCIATION

C.J. SALLY JOHNSON

6511 203rd Ave. S.W.
Centralia, Washington 98531

The Industrial Forestry Association (IFA) is a nonprofit association of companies involved in the timber industry. It was founded in 1934 with the intent of developing an adequate timber supply for the Douglas-fir industry. Towards that end, IFA started its first bare-root nursery in 1941 and has since expanded to three bare-root and one container nurseries that produce approximately 45 million seedlings every year for reforestation. The basic building block for those future trees is, of course, seed.

Seed Sources. The principal timber species grown by the IFA is Douglas-fir *(Pseudotsuga menziesii)*. Other conifers of importance are noble fir *(Abies procera)*, grand fir, *(Abies grandis)*, Sitka spruce *(Picea sitchensis)*, western hemlock *(Tsuga heterophylla)* and western red cedar *(Thuja plicata)*. These species are grown in areas of the Pacific Northwest primarily west of the Cascade mountains from the Canadian to the California borders.

All contractors belonging to IFA supply their own seed for sowing in the nurseries. This seed is obtained in a variety of ways, including seed companies such as the Brown Seed Company, to mention just one. Some companies collect their own seed and have it extracted by a seed company or they may do their own extraction. Still other companies have developed seed orchards to supply their seed needs with genetically improved seed.

The majority of the seed supplied is identified by seed zone and elevation. A few have divided the designated seed zones into breeding units that reflect a specific microclimatic site. It is important to know the seed origin as this will affect the subsequent performance of that seed.

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Seed Testing. IFA requests a seed sample of all lots scheduled to be sown in the fall prior to the spring sowing date. The germination potential of the seed, which includes both the percent germination as well as the speed of germination, is established by means of a soil table test. A standard germination test using the Association of Offical Seed Analysts Rules is also done for comparison and for insurance purposes. In addition, the number of seed per pound is established for later use in the sowing formulae calculations. The AOSA testing technique is described in Copeland (1) and will not be discussed here.

The results of the soil table germination tests are used to calculate the operational sowing rates as these results closely approximate field performance. The soil table germination values average 5 to 10% less than the standard germination test values.

The soil table tests consist of sowing stratified seed into fumigated nursery soil in a greenhouse. The soil temperature is approximately 75°F during the day and 65°F at night. The germinates are counted every 7 days for a period of 28 days. We may use various stratification times depending on the origin and past history of the seed lot. All coastal seed zones are tested at both 30 and 60 days of stratification as many of these lots show increased germination with the longer stratification. Some lots have shown increased germination with less than the standard 30 days of stratification.

We are doing some hydrogen peroxide testing on lots that are processed so late in the year that it is impossible to do proper stratification. The hydrogen peroxide test does not require stratification and takes less than two weeks to complete but it does not tell us about the rapidity of germination nor the best stratification time to achieve maximum germination in the shortest amount of time. It is, however, much better than no information at all.

Seed Stratification. The stratification process begins by soaking the seed for 24 hours at approximately 50°F. The seed is rinsed once during this period to remove any foreign material such as soil which may be carrying disease organisms. We have noticed much less mold development on our seed since this rinsing procedure was instigated. At the end of the 24 hour soak, excess water is drained from the seed, and a breather tube is inserted at the top of the plastic bag. Bags containing no more than 5 pounds of seed are hung in a cooler at 34°F for the required stratification time. The seed is checked three times a week and rolled to provide maximum exposure to the air. Water is added if the seed appears to be drying.

Seed Sowing. Once stratification is complete, the seed is surface dried in preparation for sowing. The bareroot nurseries use a "Wind River Seed Drill" to sow the seed in eight equally spaced rows in a 48 in. wide seed bed.

Sowing is scheduled any time after May 1st when the weather permits seed bed preparation. The seed is sown in densities ranging from 20 to 50 seedling per sq. ft. depending upon the fate of the seedling after two years in the seedbeds. Seedlings to be shipped for planting in the field at the end of the two years are grown at the 20 to 30 per sq. ft. densities and the higher density seedlings will be transplanted back into the nursery for another year to obtain larger seedlings that may be necessary in areas where there is high brush competition or heavy big-game browsing.

LITERATURE CITED

1. Copeland, L.O., ed. 1978, Rules for testing seed. *Jour. of Seed Tech.* 3(3):1-126.

TERMINAL BUD ABORTION IN COLORADO BLUE SPRUCE

DAVID G. ADAMS
Oregon State University Extension Service
P.O. Box 1261
Portland, Oregon 97207

Trees of Colorado blue spruce (*Picea pungens 'Glauca'*) have for many years exhibited a condition in which the primary terminal bud fails to grow normally in the spring. The severity of the condition also appears to differ from year to year. Since thousands of these trees are propagated and shipped yearly, this malady constitutes a major economic problem to the ornamentals industry of the Pacific Northwest.

Native habitat: The natural range of this tree (1) is from southern New Mexico and Arizona through the Rocky Mountains of Colorado, Utah, Wyoming, eastern Idaho, and possibly southwestern Montana. The trees are usually found in or near stream beds particularly in the more arid areas of its range. It grows at elevations of 6000 to 9000 ft. in the north and 7000 to 10,000 ft. in the southern parts. Soils are often of calcareous nature with a pH of 6.8 to 7.2. As might be expected, mean annual temperatures have an extremely broad range.

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Symptoms: Bud abortion symptoms differ slightly from plant to plant but are generally restricted to the primary terminal bud and on occasion to terminals of lateral branches. The symptoms range from complete death of the bud to slight elongation of usually no more than 1 in. The central pith area of the stem immediately below the bud usually turns brown — a characteristic indicative of boron or calcium deficiency in many plants.

Abortion of the terminal buds is usually accompanied by normal elongation of other lateral buds produced immediately below the terminals. This results in the production of trees with several leaders. In extreme cases, where abortion has occurred repeatedly to terminals and lateral branches, the resulting trees can be wider than they are tall. No insect or disease has been consistently isolated from damaged tissues.

Areas of investigation: Our first investigation led us to believe that we may be dealing with a nutritional problem. Brown pith tissue, which is indicative of boron or calcium deficiency, along with high native soil pH, strongly suggested these elements may be involved. This was of further importance because spruce are usually produced in soils of pH 5.2 to 5.8 in the Willamette Valley of Oregon. Soils were tested in many nurseries that produced both container and field-grown stock. Our initial studies indicated that trees produced with the highest amounts of calcium generally exhibited the least amount of bud abortion. Although several growers applied lime this past winter, it will probably be several years before convincing data will be available.

The other major area of investigation will be to look closely at seed source. It is well known that trees native to southern latitudes have a greater cold requirement to break dormancy than trees of the same species but native to more northern latitudes. If it is found that lateral buds (below the main terminal) have a lesser cold requirement than the terminals, our problems may be corrected by selecting seed only from the most northern sources.

The observed facts tend to bear out the above in that lateral shoots usually develop normally and the entire abortion pattern differs from year to year but is generally consistant throughout all of our growing areas.

With the above in mind, I would like to request that anyone with access to seed from native stands of Colorado blue spruce please help. I would appreciate receiving samples (about 1 oz) from throughout the natural range. I will produce seedlings in a single location. After 2 years in seed beds, the

seedlings will be distributed to nurseries throughout the area and evaluated yearly. Problems of this type often require diligent effort by growers and researchers alike.

LITERATURE CITED

1. Fechner, Gilbert, Colorado State University, Fort Collins, Colorado (Personal communication).

IMPORTANCE OF SEED SELECTION FOR CHRISTMAS TREE PRODUCTION

BARBARA M. HUPP

Drakes Crossing Nursery
19744 Girade Road, S.E.
Silverton, Oregon 97381

Equally as important to successful Christmas tree growers as it is to the timber industry is the selection of seed for plantation Christmas trees.

In the early days of Christmas tree farming, in the early 1960's, growers began to see a marked difference among trees with seed origin from different geographic areas.

This prompted provenance tests using the most popular Christmas tree species, namely *Pseudotsuga menziesii*, (Douglas-fir), *Abies procera* (noble fir), *Abies grandis* (grand fir), *Abies magnifica* var. *shastensis* (Shasta fir), *Pinus contorta* (shore pine), and *Pinus nigra* (Austrian pine).

These provenance tests were laid out, managed, and evaluated by member growers of the Northwest Christmas Tree Association, in conjunction with Oregon State University, United States Forest Service, Oregon State Department of Forestry, and Washington State Department of Natural Resources.

These provenance tests were established from northern Washington to southern Oregon to give a wide range of climatic conditions as well as inherited traits in selected sources.

Trees were evaluated for color, branch arrangement, number of buds, disease resistance, climate adaptability, form and most important, overall development rate. After all, Christmas trees are intended to be a crop to make money. The quicker the turn-over in a marketable tree the better.

For **color,** customers always prefer a dark green to blue green. A golden color is accepted in the nursery industry but not in Christmas trees.

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For **color,** customers always prefer a dark green to blue green. A golden color is accepted in the nursery industry but not in Christmas trees.

Branch arrangement and number determine the density of the tree. Five generally gives a good tree. More is better, of course. Slightly upright branches are desirable.

Disease resistance is a major influencing factor. Trees are taken from wide ranges, so naturally developed immunities in native stands are not helpful. Some trees show more tolerance than others to naturally occurring pests.

Climate adaptability: time of bud break seems to be the most important factor. Late bud break is not as subject to freezing or insect and disease infestation as early bud break. Trees are most vulnerable to insect and disease attacks when they are succulent. Late bud break time could by-pass some of these problems.

Form: the slim, tapered, pyramid is the shape everyone wants at Christmas. Shape can be altered by means of shearing, a common practice for Douglas-fir and pines. The true firs are naturally inclined to slim tapers but some sources lend themselves to shearing and shaping better than others.

Development rate has to be the most important factor. No matter how good color, branch arrangement, disease resistance, climatic adaptability and form is, if it takes a long rotation to get a good 5 to 8 ft. tree it is not economical to use that particular seed source.

All these tests paved paths for seed collections from specific areas for propagation by nurseries.

Those geographic areas chosen as the better seed sources are:

Douglas-fir — the eastern portion of Vancouver Island, Canada, at elevations above 500 feet; the area around Shelton, Washington; Cushman Lake; and areas west of Corvallis, Oregon.

Noble fir — areas around Mt. St. Helens in Washinton; the mid-Oregon Coastal Mountains, with one very specific region known as Mary's Peak, the highest peak in the Oregon Coast Range. This area has qualities not exhibited in the general Coast Range.

Grand fir — the Clearwater River drainage area in Idaho was chosen as the single best source for its needle holding qualities. The grand fir has always been a notorious needle dropper.

Shasta fir — generally the area west of Grant's Pass, Oregon proved best.

Shore pine — the Southern Oregon Coast outrated areas farther north for color and density.

Austrian pine — Russia, Yugoslavia, Turkey, and Spain rated best for color, needle length, number of buds, vigor and shearing response.

The areas mentioned received the best evaluations. There are other general areas which growers on their own have chosen for not only the earlier mentioned qualities, but for their own personal reasons. Some growers disregard all the tests and choose a single tree or an area of trees for their own planting stock. Seed is usually picked by them, cleaned, and furnished to growers like ourselves to be custom grown.

In conclusion, these tests help us as propagators choose generally accepted superior Christmas tree areas for our seed. It costs no more to plant superior seed with desirable inherited traits, so why not do so.

VOICE: In soaking the seeds, how long a soaking period do you use?

CLARK BROWN: It is the cones we are soaking prior to drying. We soak them from 15 to 30 minutes.

ED SCHULTZ: Sally Johnson, have you used the insecticide, Mesurol, to keep the birds off your pine seedlings. It is reported to have some repellent properties.

SALLY JOHNSON: No, we have not used it for this purpose. I don't believe it has a legal registration for this use.

BEVERLY GREENWELL: Dave Adams, have you considered boron deficiency as a possible cause for terminal bud abortion in the Colorado blue spruce?

DAVE ADAMS: We have not ruled it out, but in areas where we have made tests there is adequate soil boron for most trees.

BEVERLY GREENWELL: In British Columbia we have had this problem consistently for a number of years and we have noted both low boron and low calcium in these areas. Boron applications seemed to help after 3 or 4 years.

DAVE ADAMS: In Colorado they are running a series of tests, including soil tests, on this problem so more information may be available in another year.

BEVERLY GREENWELL: When you supply conifer seed to seedling growers do you also supply information on the seed source — the provenance?

CLARK BROWN: Yes, we always give information on the seed origin — seed zone, elevation, crop year, and sometimes the specific stand.

BEVERLY GREENWELL: Then how does it happen that so many seed dealers do not know where their seeds came from?

CLARK BROWN: This is a big problem, but basically it is probably because some dealers do not keep sufficient records.

WILBUR BLUHM: In regard to the boron relationsip to bud abortion in Colorado blue spruce, in tests I have,been involved with we could find no correlation between boron levels and bud abortion.

VOICE: Does Clark Brown's company use X-ray examination to determine the condition of his seed.

CLARK BROWN: No, we do not. We depend only on visual examination and on cut tests.

STRAWDUST — AN ALTERNATIVE GROWING MEDIUM

DICK TUEFEL

770 S.W. Viewmont Dr.
Portland, Oregon 97225

Because of the diminishing supply and increasing cost of barkdust and sawdust which we were using in our nursery, we have developed an alternative container medium, using materials which are locally availably in abundant supply.

This new medium is made from wheat straw that is resin-impregnated in a special treatment process. Treatment of the straw is necessary because straw normally decomposes rapidly, and requires large amounts of nitrogen when it does. It also shrinks rapidly and is full of seeds.

The treament process is as follows:

1. Bales of straw are placed in a tub grinder which rotates and feeds the straw to a hammer mill.

2. The straw is then conveyed to a mixing auger where the first set of chemicals are injected.

3. This mixture is then augered to the next machine where the second set of chemicals are sprayed on the straw. It is then augered to the cube dies where it is extruded into blocks. The extreme pressure of this extrusion process forces the chemicals into the straw and also compresses the straw so there will be little shrinkage later. The heat generated by extrusion of the straw and chemical mixture kills all seeds that may have been present and sterilizes the material.

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The treament process is as follows:

1. Bales of straw are placed in a tub grinder which rotates and feeds the straw to a hammer mill.

2. The straw is then conveyed to a mixing auger where the first set of chemicals are injected.

3. This mixture is then augered to the next machine where the second set of chemicals are sprayed on the straw. It is then augered to the cube dies where it is extruded into blocks. The extreme pressure of this extrusion process forces the chemicals into the straw and also compresses the straw so there will be little shrinkage later. The heat generated by extrusion of the straw and chemical mixture kills all seeds that may have been present and sterilizes the material.

4. The cubes are then conveyed to a storage area where they are ground to the desired particle size by a hammer mill. This produces the final product which we call "Strawdust".

This process changes the straw in six ways:

1. It is made longer lasting.
2. The pH is changed, ranging from 5.8 to 6.0.
3. It is sterilized.
4. Nitrogen in a slow-release form is added.
5. It is compressed to keep it from shrinking in the container.
6. It is made non-flammable.

Uses for Strawdust:

1. A container growing medium.
2. Soil builder in landscape jobs and gardens.
3. A mulch, to protect plants from heat, cold, and drying.

Strawdust is less expensive to use than bark or sawdust because of the fertilizer value it contains. Also, the pH has been adjusted and it has been sterilized.

Strawdust has been used in our nursery since 1979 and has been under test by Oregon State University since 1981. These tests shows that a mix of 70% Strawdust, 15% peatmoss, and 15% pumice, with no fertilizer or amendments added, has out-performed bark mixes with all the normally recommended amendments added.

Strawdust has U.S. and foreign patents pending.

COMPUTER CONTROLS FOR GREENHOUSE ENVIRONMENTS

HUGO C. WILDSCHUT

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30450 S. Candlelight Court
Canby, Oregon 97013

INTRODUCTION TO COMPUTERS

I am basically a nurseryman and I want to have a smooth, efficient controlled nursery operation. My major problem was finding a reliable system for watering and heating my nursery beds. Having a fair background in electronics, I turned to this field to solve my problem and I feel that it has been nicely accomplished.

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Mention, the word COMPUTER and a lot of people seem to get nervous. "Computerphobia" it is called. Accompanied by comments such as — too complex" — "too expensive" — "too everything" —. Nonsense. If you can tie your shoes or drive a tractor, you can operate a computer.

A computer and a shovel had one thing in common. Initially they both need you at one end to start working. However, unlike a shovel, you can walk away from a computer and it will keep on working until you tell it to stop. The computer itself has no intelligence, no mind of its own; it is simply an electronic tool, serving a real purpose by following your instructions to the letter, instructions you give it called PROGRAMMING. We will consider programming later.

A computer in reality is a very simple device. It understands only two commands, YES and NO, or TRUE and FALSE. With these two simple commands, the computer can do all the fantastic things that you have heard and read about and more. The computer can also be referred to as the the dumbest device devised by man. Why? Because when the computer is first turned on, it will just sit there and do nothing. It has no intellegence, no mind of its own; it does not know what to do, until told. If the computer is that simple, and dumb, how can it do all the things is does? PROGRAMMING is the key.

Todays computer can be divided into three groups.

GAME COMPUTERS: for example, the type your children play games with, such as ATARI.

BUSINESS COMPUTERS: big business types, as IBM or small business types, as RADIO SHACK.

The last type: the one we are interested in is the COMPUTERIZED CONTROL SYSTEMS.

For a computer to control machinery, for example, it must be customized. It must be built to do the type of controlling that the customer wants. So it is built especially to those requirements. Aircraft systems are computerized to a great degree today. Another special field, one of the most sophisticated type of control is that used for satellite orbiting. Space probes would also stand very high in the list of sophisticated controls. Still another type of customized controller is the environmental control systems for homes, business, and nursery facilities.

TERMINOLOGY

At this point it is necessary to introduce a few terms. They will help to clearify some of the statements to be made.

CPU — CENTRAL PROCESSING UNIT. The heart of the computer. It does all the processing of instructions, logic analysis, arithmetic, and many other functions.

I/O — INPUT/OUTPUT DEVICE. This unit talks to the outside world and lets the outside world talk to the computer. Instructions come into the computer and back out again. An example would be the information from a thermometer; it tells the computer that it is too hot and that cooling water is needed. This is input. Upon receipt of this information, the processor, through the program, knows that it is time to turn on a cooling spray, so a signal is sent to a solenoid valve and the water is turned on . This is output.

RAM — RANDOM ACCESS MEMORY. Memory locations that can be written to and read. It is usually a temporary location for temporary data.

ROM — READ ONLY MEMORY. A memory location that you can only read but can not change. This is the type of memory that is used to store the program that will operate the controller.

MPU — MICROPROCESSING UNIT. This is the system as a whole. Those parts that go to make up an operating unit.

HARDWARE — SOFTWARE. Hardware is the physical parts of the computer — the boards, power supply, resistors, capacitors, and the chips. The software is program.

SYSTEM CAPABILITIES

At this point I am going to stop using the word COMPUTER. Instead the word CONTROLLER will be used because that is what we want to do, to control various functions in the greenhouse in the most reliable and economical way.

It can be stated safely that the system has unlimited possibilities. Actually, anything that you can think of for the unit do, if can do, but it must have guidance. It must be programmed. If you can think of a function, it can be written into the program and the controller will carry out the instruction. In the development of this system I have taken into account the problems that I had: reliability, accuracy, and the economical aspect of the equipment. These factors I feel have been found and are reflected in the equipment that I have designed.

ENVIRONMENTAL CONTROL IN THE GREENHOUSE

In designing and developing a control system, the present stage of development allows for control of propagating bed heating, watering, variable times on and off for each bed up to 16 beds, turn on and turn off time, if desired, and a battery

backup system. This backup system will go into operation if the main power source fails. It will keep all internal functions going, time keeping, data on each bed, and will return to normal running when commercial power has been restored. It will continue from the point where it stopped. Other functions that can be added are cooling of the air in the greenhouse by turning on fans, opening louvers, or another desired method of cooling. If the greenhouse drops below a predetermined temperature, heat will be introduced into the greenhouse. Normal ventilating can also be controlled by the use of a thermostat that the controller will read and turn on and off as needed. The applications of liquid fertilizer through the water nozzles can be applied in the amounts determined by the operator. This can be done daily, weekly, monthly, or at any predetermined time. This list can go on and on.

CUSTOMIZING

In order for the controller to carry out the functions that the customer desires, it is necessary to sit down with the propagator and find out in detail what he wants the equipment to do. It must be remembered that this controller can easily replace one or two or more individuals that are now doing the work of watering, fertilizing, checking the bed heat, and making adjustments as needed, and many other duties. The controller can do all these things and more. All data coming in through the input port is checked as many times as once every 200,000th of a second, so nothing passes by the controller without action being taken, if action is needed.

Once all the objectives have been stated that the grower wants, the programmer goes to work. Programming is detailed work and requires time to arrive at the end results. However, because a lot of the basic programming has been done, it will only require some tailoring to make it fit the new conditions. The unit that I have designed takes into account all the things that I have thought of plus suggestions from others, so any new function can usually be added with little trouble. Now that the program has been written, it is time to go to the next step.

DEBUGGING

Once the program has been written and stored in a ROM, now the fun begins. You just do not turn on the controller and the water comes on, the fans start to go, and all the other factors go to work. If this happened the first time the unit is powered up, I think that all the programmers in the world would drop dead. It would truly be a miracle to have a program work in its entirety the first time. The operation of

DEBUGGING is the process the programmer goes through step by step, to see if the program does what the designer wants it to do. If it doesn't, then a change is made until the unit functions correctly. This can be a tedious job and sometimes very time consuming. Finally all parts work correctly and the final program is stored in the PROGRAM ROM and the controller is ready to go to work.

EQUIPMENT DEVELOPMENT

The first controller that I developed is called a SEQUENTIAL CONTROLLER. It is a sophisticated timer, microprocessor controlled. It allows the grower to set the number of beds to be watered, the time the bed is watered, and the interval between watering. Each bed is watered in sequence. When the last bed has been watered, the controller will start over again, the cycle is repetitive within the limits set by the grower. The setting of the limits is easily done by "thumb wheel switches". The number is displayed in a window next to the switch, so at all time the grower can see what limits have been set in the controller. There is a safety feature built into the controller which tells you by a flashing red light, if you have set the "on" time greater than the interval time. This SEQUENTIAL CONTROLLER was designed for the grower who has limited water pressure and can only run a limited number of sprinklers. For the grower who has more or less unlimited water pressure and volumes, another, second controller has been designed.

The second controller is a PARALLEL CONTROLLER, with or without high and low temperature warning. This controller is designed for the grower who has sufficient water volume and pressure to run any or all the propagating beds at a time. Really a better term to use than "beds" is "stations" because the controller is not limited to propagating beds, but can be used for field areas, can yards, or or any combination. This unit is settable for 99 stations and each station can be set independently of all others as to the cycle "on" and the cycle "off". With this arrangement, sooner or later in a day, all stations will be on at the same time. Hence the word PARALLEL CONTROLLER. An added feature built into the unit is "start" and "stop" time. For example, if you want the system to start at 8:00 a.m. and stop at 6:00 p.m., this information is entered into the system by the operator. The entry of data is done by the use of a touch pad and looks very similar to a touch type telephone except there are 20 key pads instead of the 12 found on a standard telephone. This should cause no confusion as the extra pads are marked as to their function. Now a mention of "with or without" high and low temperature warning. This function is, at the present stage of development,

only a warning circuit and will give an indication to the operator that the temperature is higher than some predetermined setting or has reached some predetermined low temperature. For the present, the operator will be required to take corrective action, such as turn on the heater, or turn on the cooling system. This will all be done by the controller in a later model.

With these two models, it is felt that a fairly large segment of propagators and growers should find them very useful and reliable tools. The controller is more reliable then doing the work manually. There are two other models in the offing, which will be even more helpful. Model 3 will have all the features of the "Parallel Controller" but with the added capability of moisture sensing. This means that the grower can set the controller to give him the moisture that he needs for the best growing conditions, and the controller will maintain these conditions until directed to change. This is set by the grower the way he wants it. The fourth controller will provide the grower with a video screen that will keep him informed at all times about conditions at each station, what the "on" and "off" time are, or how much time is left in a cycle then in progress. If there are failures, such as water pressure, high heat, low temperature, a malfunction of a fan or pump and many other data, this will be displayed on a video screen for all to see. If an emergency exists, additional devices can be activated to warn the grower what and where the malfunction has occurred; for examples. ring a bell, flash a light, blow a horn, etc. If needed, this information can be displayed in English and Spanish simultaneously. There is no limit as to what can be done to make the job of propagating and growing easier and more reliable. A controller will not forget, nor will it make a mistake. The grower has to enter the instructions to the controller through the use of the key board and the controller will do the rest. If you enter the wrong data, the results will be wrong, so great care must be taken in passing on the instructions to the controller, but this is not difficult.

SUMMARY

In summarizing this discussion on computers and controllers *it is probably suffice to say that controllers that are micro*-processor-designed will do many things for the grower that are now done with less reliability and accuracy, and certainly at a greater savings in money and time. As I stated in the beginning, I designed a controller as a matter of necessity after having experienced the loss of my first crop of seedlings. I further wanted a system that was solid state, which means — no moving parts. At least no moving parts in the controller.

Externally there are solenoid valves and other devices that have moving parts but these can be kept to a minimum. Relays are a source of many problems; now the technology provides a means of avoiding such problems. The microprocessor has given me the reliability and flexibility that I need. Prsently I have one system running as a test installation to determine if there are any bugs in the program that need to be changed. Through the kindness of Ed Schultz of Calorwash Nursery, Aurora, Oregon I have been able to test my prototype with complete success. I wish to thank him for his patience and help.

WESTERN REGION 1983 AWARD OF MERIT

Presented by Phil Parvin at the
Western Region Annual Banquet

The Western Region's 1983 Award of Merit recipient is a distinguished scientist and a former Professor of Horticulture at Rutgers University in New Jersey. He has been a nurseryman in Long Beach, Washington, for many years. He is the author of numerous articles in garden publications and has lectured to garden clubs across the country. He is the author of "Small Fruits for Your Home Garden" and "Getting Started with Rhododendrons and Azaleas". He is a Past-President of the Washington State Nurseryman's Association and was on the Board of Governors of the American Association of Nurserymen. He is a Past-President, and has been a National Director, Executive-Secretary, Editor of the Quarterly Bulletin, and recipient of the Gold Medal Award of the American Rhododendron Society. He is a Board Member of the Rhododendron Species Foundation. He is a past member of the Executive Committee and a Past President of the IPPS Western Region. Our 1983 Award of Merit Recipient is Dr. J. Harold Clarke of Sun City, Arizona.

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WILLOW WATER AND ROOTING RHODODENDRON CUTTINGS

W. M. PROEBSTING

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Abstract. Cuttings of *Rhododendron* 'Britannia', 'Crest', 'Dr. Dresselhuys', 'Ignatius Sargent' and 'Jean Marie de Montague' were treated with auxin, or auxin + willow water extract, and rooted under mist. The extract failed to stimulate rooting or root quality in any of the cultivars.

REVIEW OF LITERATURE

Rooting cofactors, chemicals that stimulate root initiation in combination with auxin, have been studied for many years, but remain poorly understood. The working model of root stimulation in plants remains essentially that of Bouillenne and Bouillenne (1) who proposed that "rhizocaline", the stimulating substance, is composed of three components: 1) a specific factor, translocated from the leaves; 2) a nonspecific factor (auxin); and 3) a specific enzyme located in the cells of certain sensitive tissues that activates 1 and 2.

Cofactors have been extracted from various woody plant and partially characterized using the mung bean bioassay (2,3). A cofactor from willow extracts was similarly demonstrated (4,5,7), and later reported to have potent stimulatory activity in several difficult-to-root woody species (8,9). The purpose of this paper is to report the results of a study designed to test the efficacy of crude *Salix purpurea* extracts on the rooting of several rhododendron hybrids.

MATERIALS AND METHODS

Young shoot tips of Arctic willow or purple willow *(Salix purpurea)* were collected August 30, 1982, frozen at -60°C and pounded to loosen the bark from the wood. About 250 g of willow were steeped in 1.5 liter of distilled H_2O at 50°C for 2.5 hr. The bases of 50 cuttings each of *Rhododendron* 'Britannia' (Brit), 'Crest', 'Dr. Dresselhuys; (Dr. D), 'Ignatius Sargent' (IS), and 'Jean Marie de Montague' (JM) were soaked overnight (18 hr.) in the willow extract. The bases of another 50 cuttings of the same cultivars were soaked for 18 hr. in distilled H_2O. After the soak, all cuttings were dipped for 5 sec. in a 15% solution of Dip n' Grow (1500 ppm IBA, 750 ppm NAA), stuck in a medium composed of coarse quartz sand and peat (4:1), then maintained under mist. There were 5 replicates of 10 cuttings in each treatment. The rooting of the cuttings was

evaluated February 7 to 10, 1983. Cuttings were graded for the presence or absence of roots and the root system subjectively rated as good, fair, or poor.

RESULTS

The treatment of rhododendron cuttings with Arctic willow extract failed to stimulate rooting within the 5-month test period (Table 1). Neither the number of cuttings rooted, nor the quality of the rooted cuttings was significantly better in either treatment. Cvs. Brit, Crest, Dr. D, and IS are generally regarded as difficult to root, and were used for that reason. In this trial, however, Cv., IS rooted readily and developed substantial root systems in both treatments. The overall lower quality of the willow-treated Cv. IS root systems was nearly significant at the 5% level. The lower rooting percentage of willow-treated Cv. Crest cuttings was close to significance at the 10% level. A high percentage of Cv. JM rooted, but the root systems were still small and delicate on the evaluation date.

Table 1. Rooting percentage and percent rated good after treatment with water + auxin, or willow extract + auxin, of 5 rhododendron cultivars. Means were not significantly different according to analysis of variance.[1]

	Treatment			
	Water		Willow extract	
Cultivar	Percent Rooted	Percent Rated Good	Percent Rooted	Percent Rate Good
'Britannia'	14	0	10	0
'Crest'	20	2	8	4
'Dr. Dresselhuys'	34	2	38	2
'Ignatius Sargent'	100	96	100	72
'Jean Marie'	82	16	76	8

[1] Five replicates of 10 cuttings per treatment.

DISCUSSION

The published evidence of root promoting activity of willow originated with an observation that centrifugation of willow cuttings stimulated rooting (4). Data were later presented suggesting that centrifugation stimulated rooting by increasing stem ethylene concentrations (6). Applied ethylene also promoted rooting of willow. When the water that the willow cuttings were centrifuged in was tested, significant rooting cofactor activity, other than ethylene, was detected by the mung bean bioassay (4,5). Cofactor activity in the mung bean test was also reported in several other woody species (7).

Two sources suggest that willow extracts promoted rooting of several difficult-to-root woody species (8,9), but there ap-

pear to be no data describing these effects. Instead, propagators have tried to glean information from other sources and with apparently mixed results.

There was clearly no positive effect of the willow extract on the quantitative or qualitative aspects of rooting of the *Rhododendron* cultivars that we tested. These results indicate that a great deal remains to be discovered about the use of the willow rooting factor. Species, date of extraction, methods of extraction, concentration, methods of application and problems such as Kawase's statement that "impurities in the crude extract from willow cuttings from time to time completely nullified the root promoting effect" (9) are obstacles to overcome.

The existence of extractable cofactors that stimulate rooting of woody plants that auxin cannot is an attractive and important concept in plant physiology, but it has yet to be demonstrated. The willow factor is an interesting possibility and deserves further objective research.

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JIGS FOR CRATING LINERS FOR SHIPMENT OF SMALL NURSERY PLANTS

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This paper describes how we rack up our flats of small plants for shipment. We use wooden flats for this. I have yet to see a plastic flat that would work well.

Our first jig was a backless box or rectangle made of 1×12 in. rough planks and stood on end. Cleats were nailed on the interior of the sides on which to set flats. The inside dimensions were the width of the flats, by about 5½ ft tall. The bottom board was 3½ ft long. One side had a clasp fastener at the top and was hinged at the bottom so that it could be opened and laid down. We would set the flats into this rectangle like so many shelves, with the heavy end boards exposed on the front and back sides. Then we would take four narrow boards and nail them two to each end of the shelved up flats. When this was completed the side of the frame was opened and the rack of flats was lifted out. There was then one diagonal strip nailed to one end of the flats and another diagonal strip to one side to hold the rack rigid. We had two of these frames, one with closely spaced cleats and the other with cleats farther apart for different height plants. However, we no longer use these frames.

When these first frames began to wear out we did some major redesigning and had our local blacksmith build two more jigs or frames using angle iron. These are much easier to use than the wood frames and very durable. They are built on an 18 in. square base of 1½ in. angle iron with two 6 in. stabilizing wings at the back so there is no danger of it falling backward. At the back are two uprights of angle from 48 in. tall and 18 in. apart, outside measurements. These are tied together by two 1 in. bars, 3½ and 44½ in. from the ground. There is a third angle iron welded to the forward edge of the left upright to serve as a corner guide to keep all the flats lined up straight when they are set into the jig. Onto the two uprights are fastened 15 in. arms of angle iron projecting straight forward. One frame has 7 spaces for flats 7½ in. apart and the other has 10 spaces 5 in. apart. If the plants are taller yet we use the second frame but use only every other set of arms. After the frames were constructed they were sprayed with Rustoleum paint.

In using the frames we just set the wooden flats of plants on the arms cross ways and slide each flat into the angle-iron corner at the back. The thick board ends of the flats are at the sides. We use 6 regular, old fashioned building laths 4 ft. long for the supports to hold the flats all together. Two laths are stapled onto each of the flats, one diagonal strip across the face, and another diagonal across one end. We have given up using a hammer and nails for securing the racks although they work fine and are currently using a compressed air staple gun. It is so much faster.

A rack of plants thus constructed is surprisingly sturdy and easily handled. We use 40 to 50% soil or sand in most of our rooting or growing media, so a 4 ft. rack of plants is about as much weight as can be conveniently handled. Two or three of these racks fit nicely into the bucket of our tractor for easy loading into a truck.

CUTTING PROPAGATION COSTS FOR FRASER PHOTINIA AND TAM JUNIPER

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Abstract. Cutting propagation costs for *Photinia* × *Fraseri* Dress. and *Juniperus sabina* L. 'Tamariscifolia' were determined to be 20.5 and 13.1 cents per saleable rooted cutting, respectively. Sticking, rooting, and growing cuttings was 71.2 and 73.3 percent of total cost. Securing cuttings was 13.2 and 9.2 percent, overhead 10.7 percent for both, and operating capital interest 4.9 and 6.9 percent of total propagation cost. Labor was the largest single cost in producing cuttings.

INTRODUCTION

Nursery production cost studies have been made in the United States and elsewhere, but few propagation cost studies are reported. Baldwin and Stanley (2) discussed propagation costs, their discussion in part based upon this study. They cover various inputs and provide a suggested propagation cost worksheet.

This study is in response to the request by a group of Willamette Valley, Oregon nursery growers for information on propagation and productions costs. They were concerned that production cost information was inadequate for pricing of their stock.

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Procedures used in this study are not unique. They have been very successfully used to determine production costs of many diverse agricultural enterprises in Oregon for many years. These procedures are easily adapted to the unique characteristics of various enterprises and they adapted well to this propagation cost study.

METHODS AND MATERIALS

A meeting was held with interested growers. They shared ideas on needed cost information and propagation procedures. A worksheet, "Computing Costs of Plant Propagation," was then developed and sent to participating growers in the spring of 1980.

Two commonly propagated nursery plants were selected for this study. *Juniperus sabina* L. 'Tamariscifolia' is easily propagated from cuttings. *Photinia* × *Fraseri* Dress. is more difficult. Each is typical of many plants propagated by nursery growers in the Willamette Valley.

Six growers provided cost data for the juniper, filling out the worksheet, and five provided data for the photinia. All data was then compiled and summarized.

This study was updated in August, 1983. Input costs were changed to reflect inflationary increases since the original study was made.

RESULTS

Results of the 1983 updated study are given in the following tables.

Table 1. Summary of cutting propagation costs of Fraser photinia.[1]

Operation	Average cost, cents per cutting	Cost range, cents per cutting	Percent of total propagation cost
Cost of cuttings before sticking	2.7	2.4- 6.7	13.2%
Rooting and growing cuttings	14.6	8.7-18.4	71.2
Overhead costs	2.2	0.8- 4.1	10.7
Operating capital interest	1.0	0.3- 2.2	4.9
Total	20.5	16.4-27.1	100.0

[1] summary of 5 growers

Table 2. Cost of Fraser photinia cuttings before sticking.

Cutting source	Average cost, cents per cutting	Cost range, cents per cutting
Cuttings from plants away from nursery, or from other than stock plants	1.9¢	0.7-2.7¢
Cuttings from stock plants	2.5	2.2-2.9
Purchased cuttings	3.8	(one grower)

Table 3. Cost of rooting and growing cuttings of Fraser photinia.

Cost item	Average cost, cents per cutting	Cost range, cents per cutting	Percent of total propagation cost
A. Housing and equipment	2.8¢	1.8- 5.3¢	13.7%
B. Propagation media[1]	1.7	0.7- 4.6	8.3
C. Preparing and sticking cuttings	4.6	2.4- 7.3	22.4
D. Rooting and growing cuttings[2]	1.4	0.3- 2.3	6.8
E. Harvesting cuttings	1.9	0.6- 3.7	9.3
F. Waste disposal and cleanup	0.6	0.4- 0.8	2.9
G. Utilities	1.6	0.3- 4.6	7.8
Total	14.6	8.7-18.4	71.2

[1] includes components and labor for mixing, cleaning, and placing.
[2] includes labor and materials for disease and insect control, plant shaping, diseased and dead plant removal, fertilization, environmental control, growth regulators, etc.

Table 4. Overhead costs for propagation of Fraser photinia cuttings.

Cost item	Average cost, cents per cutting	Cost range, cents per cutting	Percent of total propagation cost
A. Advertising and promotion	0.3¢	0.06-0.9¢	1.5%
B. Dues, licenses, and fees	0.2	0.2[1]	1.0
C. Accounting, bookkeeping, and secretarial services	0.4	0.12-1.2	1.9
D. Miscellaneous travel expense	0.5	0.1 -0.9	2.4
E. Labor management[2]	0.2	0.1 -0.4	1.0
F. Operation management[3]	0.6	0.2 -1.7	2.9
Total	2.2	0.8 -4.1	10.7

[1] costs identical for all growers
[2] 20 percent of hired labor costs for rooting and growing cuttings, plus hired labor for secretarial, accounting, and bookkeeping services, but not for services not involving hiring labor by nursery management; a cost for managing hired labor.
[3] cost for managing the nursery operation; 15 percent of total cash costs for rooting and growing plus overhead cash costs.

Table 5. Summary of cutting propagation costs of tam juniper.

Operation	Average cost, cents per cutting	Cost range, cents per cutting	Percent of total propagation cost
Cost of cuttings before sticking	1.2¢	0.2- 2.1¢	9.2%
Rooting and growing cuttings	9.6	3.3-14.3	73.3
Overhead costs	1.4	0.3- 3.3	10.7
Operating capital interest	0.9	0.2- 1.8	6.9
Total	13.1	5.1-20.0	100.0

Table 6. Cost of tam juniper cuttings before sticking.

Cutting source	Average cost, cents per cutting	Cost range, cents per cutting
Cuttings from plants away from nursery, or from other than stock plants	1.1¢	0.2-1.5¢
Cuttings from stock plants	0.7	0.6-0.8
Purchased cuttings	1.7	1.4-2.1

Table 7. Cost of rooting and growing cuttings of tam juniper.

Cost Item	Average cost, cents per cutting	Cost range, cents per cutting	Percent of total propagation cost
A. Housing and equipment	1.3¢	0.1- 2.4¢	9.7%
B. Propagation media[1]	0.6	0.2- 1.1	4.9
C. Preparing and sticking cuttings	3.5	1.1- 7.3	27.0
D. Rooting and growing cuttings[2]	0.9	0.1- 2.3	6.9
E. Harvesting cuttings	1.5	0.5- 3.7	11.8
F. Waste disposal and cleanup	0.3	0.1- 0.8	2.6
G. Utilities	1.4	0.1- 3.7	10.3
Total	9.6	3.3-14.3	73.3

[1] see note 1, table 3
[2] see note 2, table 3

Table 8. Overhead costs for propagation of tam juniper.

Cost Item	Average cost, cents per cutting	Cost range, cents per cutting	Percent of total propagation cost
A. Advertising and promotion	0.1¢	0.01-0.4¢	0.9%
B. Dues, licenses, and fees	0.02	0.01-0.1	0.2
C. Accounting, bookkeeping, and secretarial services	0.2	0.1 -0.3	1.5
D. Miscellaneous travel expense	0.4	0.01-1.3	3.4
E. Labor management[1]	0.3	0.02-0.7	2.3
F. Operation management[2]	0.3	0.02-1.1	2.5
Total	1.4	0.3 -3.3	10.7

[1] see note 2, table 4
[2] see note 3, table 4

DISCUSSION

Labor is the principal cost factor in propagation of cuttings of tam juniper and Fraser photinia. More than 50% of total cost was found to be labor. Hired labor accounted for about 80% of total labor cost.

The high labor requirement procedures in the propagation operation are responsible for the cost distribution in summary Tables 1 and 5. The preparation, sticking, rooting, and growing

of cuttings, referred to above as "rooting and growing," with intensive labor requirements, is more than 70% of total cost of producing saleable rooted cuttings. Labor merits the most consideration for improving efficiency and reducing costs in propagating cuttings.

Purchased cuttings were the most costly. Since the price of cuttings is not the major cost factor in cutting propagation purchasing cuttings may still result in greater overall efficiency in some nursery operations.

The cost of producing saleable rooted cuttings of Fraser photinia increased by 33.1% from 1980 to 1983, and tam juniper by 12.0%. Some of this increase reflects corrections in previous reporting by growers, but much is attributed to inflationary cost increases. The 1983 figures are considered substantially more accurate than those for 1980.

The tables illustrate a wide cost range for most operations and production items, for both direct and indirect costs. This reflects the inherent differences between growing operations and management styles. Most are designed and organized to use a production system unique to the nursery and to provide certain efficiencies in the operation.

Several growers participating in this study were surprised to learn the actual cost of producing saleable rooted cuttings. Some were selling or inventorying them below cost.

Note: A form has been prepared for use by plant propagators in determining their propagation costs. It consists of 5 sections. Section I is for determining costs of cuttings before they are stuck. Sections II, III, and IV are for determining costs in rooting and growing cuttings to a salable size. Section V brings costs of all sections together for a total per cutting cost at salable size. This form is available free of charge by writing to the senior author, Wilbur Bluhm, 743 Linda Ave., N.E. Salem, Oregon 97303.

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USING GEOTHERMAL HEAT PUMPS IN A PROPAGATION NURSERY

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The term "geothermal" could perhaps be misleading if one thinks of geothermal as meaning hot water out of the ground. Our water comes from the ground at 52°F and is used successfully with heat pumps for propagation of cuttings in heated soil beds. No benches are involved, and we do not heat the air.

In our main propagation greenhouse, the heated soil block is 14,000 sq. ft. with an unheated 15 to 20 ft. perimeter to reduce heat loss to the outside.

We use a low temperature (80° to 90°F) system. Water is circulated in the beds through ½ in. PVC pipe placed approximately 4 in. apart and buried 1 to 2 in. beneath the surface.

In order to distribute the heat evenly, we plumbed the system to force the water to travel the same distance for all the beds, whether it be the first bed or the farthest one at the end of the house.

Beds are plumbed in sets of two. The warm input line feeds each set through the manifold of its first bed, and the water is returned through the second bed.

The return water from all beds flows into a 3 in. cold return pipe, picking up water from the outputs of each additional set of beds as it continues away from the pump. When it receives the cold water from the farthest bed, it makes a "U" turn and flows directly back to the pump.

Oregon offers an energy-saving tax incentive which requires, for a geothermal installation, a heat pump with a COP (Coefficient of Performance) of 3. The 3 COP = the ratio of heating produced from 1 BTU of energy. Thus, it must be three times more efficient than conventional electric heat.

To locate a heat pump to meet this COP requirement, we made an extensive research and located the Hydron, manufactured in Michigan, for this new installation. Our former five 5-hp heat pumps were satisfactory, but they were no longer manufactured.

We have been using water-to-water geothermal heat pumps for several years. For us, the advantage of the water to water type over the air type heat pump is evident since our well water is 52°F year round, regardless of outside air tem-

perature. Obviously, 52°F water could have more heat than 20°F air temperature.

We were already using our irrigation pumps to supply water to our former heat pumps. The two uses are compatible since usually we do not irrigate and heat at the same time.

To receive maximum use of the electricity required for pumping, we decided to use the well water twice. After the 52°F water goes through this heat pump, it is exhausted at approximately 44°F. This chilled water is then sent through the Hydron heat pump which extracts an additional 8°F approximately. The efficiency, even with this chilled water still exceeds a COP of 3.

How do we get rid of this much exhausted water? We already had an oversized rock-filled drainfield to care for the water which drained from our large greenhouses, several of which are 200 ft. long. This chilled water is exhausted into that. This means, actually, that we are only taking the water out of one place in the ground and putting it back in at another location.

To help you compare costs:

A COP of 3 produces 3 BTU's of heating from 1 BTU of electric energy input.

Resistance electric heat	= 3420 BTU's per KWH
Oil	= 105,000 BTU's per gallon, figuring approximately 75% boiler efficiency
105,000 BTU's	= 30.77 KWH.
At 5¢ per KWH	= $1.54
Heat pump with COP of 3 (3 BTU's of heating from 1 BTU of electric energy)	= 52.4 cents
Plus electricity to pump the well water, approximately 20%	= 62.4 cents

This is the equivalent of paying 62.4 cents per gallon for oil.

At the time we installed our heat pumps, electricity was less than 3¢ per KWH. But even with its costing about 5¢ now, we figure we are still saving about one-third as compared to heating with diesel oil.

Whether a heat pump would be practical for you would depend upon the cost of electricty and how efficient your boiler was.

If you are changing from an existing hot water system it is easy to see that you would need to greatly increase your

heating area (pipes or heat exchangers) to compensate for the lower water temperature.

You must also calculate the initial cost of a heat pump. But considering today's high heating costs, we have found that a heat pump can pay for itself within a few years.

VIRUS ERADICATION THROUGH IN VITRO TECHNIQUES

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Abstract. *In vitro* heat therapy was successfully used in combination with shoot-tip culture to generate grapevine fanleaf virus-free *Vitis vinifera* 'Ranny Vira' but not grapevine leafroll-free *V. vinifera* 'Schuyler' or *V. piasezkii*. A combination of shoot tip culture and *in vitro* chemotherapy with either DHPA or vidarabine was ineffective in generating grapevine leafroll-free *V. vinifera* 'Limberger' while ribavirin appears more promising.

INTRODUCTION

Two important diseases of grapevines are grapevine fanleaf (GFL) and grapevine leafroll (GLR). Both have inflicted serious economic losses to the grape-growing industry. Consequently all new introductions of grapevines into Canada are indexed for these diseases at Saanichton as part of the national plant quarantine program.

New introductions found to be infected need to be cleaned up before they are released for commercial propagation. The conventional treatment consists of growing the infected plants in a heat therapy chamber, where they are subjected to a continuous heat treatment at 38°C. After 100 days 2 cm shoots are removed and grafted onto the appropriate virus-free woody indicator. The grafted indicator plants are then monitored for symptom expression. Only some 48% of the tips generated by this method are free of grapevine fanleaf virus (GFLV). With GLR the success rate is lower. At least part of the reason for the fact that the proportion of pathogen-free tips is relatively low may be that only large shoot tips can be taken from the heat-treated grapevines for grafting onto the woody indicators.

A simple solution to this aspect of the problem lies in combining heat therapy with tissue culture. Much smaller shoot tips can be excised from grapevine tissue cultures heat treated *in vitro* than from conventionally heat-treated plants,

heating area (pipes or heat exchangers) to compensate for the lower water temperature.

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A simple solution to this aspect of the problem lies in combining heat therapy with tissue culture. Much smaller shoot tips can be excised from grapevine tissue cultures heat treated *in vitro* than from conventionally heat-treated plants,

thus making it more likely that the tip is virus-free. Additional advantages of this procedure are a considerable reduction in the space requirement, as each cultivar can be accommodated in a 125 ml Erlenmeyer flask, and a substantial saving in energy costs, as only a small controlled environment cabinet needs to be heated instead of a small room. A great deal of time can also be saved in releasing large numbers of plants to the industry. The shoot tips from the heat-treated cultures are used to initiate tissue cultures from which shoots are excised, rooted, potted, and indexed. Those cultures which are then identified as disease-free can be rapidly mass propagated *in vitro* to generate large numbers of clean stock plants. Subcultures can also be maintained at cool temperatures (8°C) as *in vitro* repository of virus-tested stock. The movement, both internationally and nationally, of such virus-tested clonal germplasm might also be greatly facilitated, as the transfer of *in vitro* cultures eliminates the risk of disseminating soil-borne pathogens.

A different *in vitro* technique for generating virus-free plants from virus-infected ones is the addition of antiviral drugs to the tissue culture medium. This approach offers all of the advantages mentioned above for *in vitro* heat therapy. In addition *in vitro* chemotherapy eliminates the heating requirements and thus offers an even greater reduction in energy costs.

The objectives of the present experiments were to determine: a) if *in vitro* heat therapy could be used, in combination with shoot tip culture, to generate disease-free grapevines from GFLV- or leafroll-infected plants and, b) if a combination of shoot tip culture and *in vitro* chemotherapy could be used to generate leafroll-free grapevines.

MATERIALS AND METHODS

Tissue culture. Media and procedures for culture initiation, proliferation and rooting were as previously published (20), except where otherwise noted.

***In vitro* heat therapy.** The grapevines used in this experiment were *V. vinifera* 'Ranny Vira' and 'Schuyler' and *V. piasezkii*. When indexed by the Plant Quarantine section the first was found to be infected with GFLV and the last two with grapevine leafroll. Tissue cultures of these grapevines at the stage of *in vitro* shoot proliferation were placed in Conviron chambers under the following heat and light regimes: 6 h at 39°C followed by 18 h at 22°C with a 16 h photoperiod at 18 $\mu Em^{-2}s^{-1}$ (approximately 1200 lux), the 39°C treatment beginning 6 h after the start of illumination. At selected intervals

shoot tips 2 mm in length were excised from the heat-treated cultures and used to initiate fresh cultures. These were then maintained at 22°C with a 16 h photoperiod (20). Shoots were excised from these cultures, rooted, and transferred to a mist chamber, and later to a greenhouse.

***In vitro* chemotherapy.** DHPA ((S)-9-(2,3-Dihydroxypropyladenine) or vidarabine (9-β-D-arabinofuranosyladenine) was added to grapevine initiation medium, prior to autoclaving. Cultures of *V. vinifera* 'Limberger' were initiated in these drug-containing media and were later transferred to drug-containing proliferation media. At various intervals 2 mm shoot tips were excised from the cultures and placed on drug-free grapevine initiation medium. When these subcultures reached the shoot proliferation stage, shoots were taken, rooted, and grown on as for the *in vitro* heat therapy experiment. Ribavirin (Virazole) (1-β-D-ribofuranosyl-1,2,4-trizole-3-carboxamide) was also tested as above except that in this case 2 cm long shoots were excised from *V. vinifera* 'Limberger' cultures actively proliferating in drug-free medium and were placed in ribavirin-containing proliferation medium. At various intervals, 2 mm shoot tips were excised and subsequently handled as above.

Indexing. Testing for the presence of GFLV was carried out by enzyme-linked immunosorbent assay (ELISA) (5) on tissue cultures initiated from the plants which had been regenerated after the *in vitro* heat treatments and which had been maintained in the greenhouse for approximately two years. Tissue cultures of GFLV- and leafroll-free *V. vinifera* 'Liemberger' were used as negative controls and cultures of GFLV-infected 'Ranny Vira' were used as positive controls. The plates were read on a Titertek Multiskan microplate reader (Flow Laboratories, Ont.) and samples giving an absorbance reading at 405 nm of at least twice the value of the negative control were considered positive for GFLV. Testing for leafroll was done by monitoring the plants for grapevine leafroll symptom expression. Readings were taken two years after the treatments were applied. In all cultivars tested, *V. vinifera* 'Schuyler', 'Limberg' and *V. piasezkii*, interveinal reddening accompanied with an angular downturn of the edges of the basal leaves were considered to indicate leafroll.

RESULTS

***In vitro* heat therapy.** A treatment duration as brief as 17 days was sufficient to generate GFLV-free *V. vinifera* 'Ranny Vira' although not all tips were virus-free (Table 1). All the tips obtained after 28 days of heat treatment gave rise to

GFLV-free plants. In contrast, this treatment was not successful in eliminating leafroll in either of the grapevine cultivars tested (Table 1). A treatment duration of 113 days yielded 2 tips of *V. vinifera* 'Schuyler' which appeared to be disease-free. However, further testing is required to confirm these results.

Table 1: Effect of *in vitro* heat treatment on the elimination of grapevine fanleaf or grapevine leafroll.[1]

Duration of treatment[2] (days)	Number of tips producing uninfected cultures/ number of tips taken		
	GFLV	GLR-1	GLR-2
17	1/2	--	0/1
21	--	0/2	--
28	2/2	0/1	0/1
37	--	0/2	--
39	--	0/1	--
40	3/3	--	0/2
47	--	0/1	--
62	--	0/3	--
66	--	0/1	--
72	--	0/2	--
77	--	0/1	--
82	--	0/3	--
85	--	0/1	--
99	--	0/1	--
112	--	--	0/1
113	--	2/3	--

[1] The GFLV-infected grapevine was *V. vinifera* 'Ranny Vira' and the leafroll -infected grapevines were *V. vinifera* 'Schuyler' (GLR-1) and *V. piasezkii* (GLR-2).

[2] Temperature cycle consisted of 6 h at 39°C followed by 18 h at 22°C, the high temperature being applied 6 h after the start of the light cycle. Light cycle was 18 $\mu Em^{-2}s^{-1}$ for 16 h followed by darkness for 8 h.

***In vitro* chemotherapy.** DHPA at a concentration of 10 mgl^{-1} was not effective in eliminating leafroll in *V. vinifera* 'Limberger' (Table 2). While 1 out of 2, 1 out of 3 and 1 out of 3 tips taken at 86, 100 and 112 days, respectively, yielded plants which did not clearly show symptoms at the time of writing, the condition of these plants is such that they cannot be unequivocally considered leafroll-free. This view is supported by the results obtained with a concentration of 15 mgl^{-1} DHPA. The 3 tips taken after a treatment period of 86 days and that taken after 100 days all yielded plants which clearly show symptoms of grapevine leafroll. The tip taken at 112 days from the culture subjected to 15 mgl^{-1} DHPA yielded plants which are still of uncertain status.

Vidarabine, at a concentration of either 10 or 20 mgl^{-1}, was ineffective in generating leafroll-free shoot tips (Table 3).

A ribavirin treatment for 32 days at a concentration of 10 mgl^{-1} resulted in the production of tips which appear to be leafroll-free, based on symptom expression 2 years after the

treatment was applied (Table 4). Shorter treatment durations at higher concentrations of the drug gave similar results.

Table 2. Effect of *in vitro* chemotherapy with DHPA on the elimination of grapevine leafroll.[1]

Duration of treatment (days)	Number of tips producing uninfected cultures/ number of tips taken		
	Concentration (mg l^{-1})		
	0	10	15
50	0/1	--	0/1
67	0/3	--	0/3
69	0/4	0/3	0/3
81	0/2	--	0/2
86	0/2	1/2	0/3
100	0/2	1/3	0/1
112	0/2	1/3	1/1

[1] *V. vinifera* 'Limberger' was used.

Table 3. Effect of *in vitro* chemotherapy with vidarabine on the elimination of grapevine leafroll.[1]

Duration of treatment (days)	Number of tips producing uninfected cultures/ number of tips taken		
	Concentration (mg l^{-1})		
	0	10	20
59	0/3	0/2	0/1
64	--	0/1	1/1
71	1/1	0/2	--
76	--	0/1	0/1
85	0/2	0/1	--
90	--	0/1	--
99	0/1	0/1	--
104	0/1	0/1	--
114	--	0/1	--

[1] *V. vinifera* 'Limberger' was used.

Table 4. Effect of *in vitro* chemotherapy with ribavirin on the elimination of grapevine leafroll.[1]

Duration of treatment (days)	Number of tips producing uninfected cultures/ number of tips taken					
	Concentration (mg l^{-1})					
	0	10	15	30	45	60
14	--	0/3	--	0/2	--	--
18	--	0/1	--	2/3	1/1	1/1
26	--	--	--	--	--	1/1
32	0/1	2/3	1/2	1/1	1/1	--
43	1/1	1/3	2/2	1/1	--	1/1
59	--	2/2	1/1	2/2	2/3	1/1
101	1/1	--	--	2/2	1/1	--
115	--	--	--	1/1	--	--

[1] *V. vinifera* 'Limberger' was used.

DISCUSSION

Viruses are, by definition, obligate intracellular parasites. They depend for their multiplication on the biochemical machinery of the cells they infect. The virions, or virus particles, consist essentially of a nucleic acid genome surrounded by a shell composed entirely or partly of protein. This shell, or capsid, protects the virus genes against digestion by ubiquitous nucleases and is sometimes involved in the attachment of a virion to the outer membrane of a susceptible host cell. Although there are variations from one virus to the next, the following is a fairly comprehensive list of the events involved in virus multiplication: a) penetration of the viral nucleic acid or of the entire virion into the host cell, b) uncoating (removal of the protein shell surrounding the viral genes), c) expression of "early" genes, d) replication of the viral nucleic acid (the viral genome is used as a template in the manufacture of hundreds of copies of itself), e) expression of "late" genes, f) encapsidation (each copy of the viral genome becomes surrounded by a protein shell) and, g) release of the progeny virions. The newly manufactured virus particles can then infect more host cells, if the opportunity arises, and begin the process anew.

Any treatment designed to generate virus-free growing points in virus-infected plants must consequently interfere with one of the above events while still allowing normal plant metabolism to proceed relatively unhindered. Meristem culture and shoot tip culture (a shoot tip being defined as the apical meristem plus one or more leaf primordia) have been shown to be of great value in eradicating certain virus diseases in plants. One of the first instances was the production of virus-free dahlias in 1952 (15). Numerous reports have since been published of excellent results obtained using these methods (16,22). The success of the procedure is generally attributed to the uneven distribution of the virus within the plants (12), the meristematic areas often being virus-free. In these instances the meristematic area at the shoot tip may, through rapid division, move away from the infected cells faster than the progeny virus particles can migrate toward it. Alternatively, the success of the method may be due to some inactivating factor produced by the explant or to the effect of some constituent of the culture medium on the virus (10). The block in the multiplication strategy of the virus, according to the above theories, might take place at the extracellular stage. An intracellular block to virus replication may also be operating, according to the suggestion that the excision of small tips temporarily disorganizes the growth processes of the cells near the meristematic dome and that host cell enzymes required for

one or more steps of viral replication become unavailable (14). Virus eradication using shoot tip culture would thus be more efficient the smaller the explant and the lower the virus concentration in the tips (22).

Certain viruses cannot be eradicated simply by meristem or shoot tip culture. Their rates of multiplication and migration are such that they can keep up with shoot tip growth. In these instances, where virions are present in the area immediately next to the apical dome or possibly within it, the plant needs some outside assistance in producing virus-free tips. Conventional heat therapy techniques have provided the solution in many cases and heat therapy combined with meristem or shoot tip culture has offered the additional advantage that very small tips could be taken from the heat-treated plant material. The data presented in this report indicate that 2 mm shoot tips excised from heat-treated grapevine tissue cultures are free from GFLV. This is in agreement with a recent report (1). The observation by those authors that GFLV is not eliminated simply by shoot tip culture, without heat treatment, was also confirmed in our laboratory. The rationale for indexing tissue cultures rather than plants maintained in the greenhouse is that the cultures are not subject to re-infection or infection with other pathogens and that routine spraying against various pests is not required. Furthermore, GFLV titers in tissue-cultured grapevines are as high as or higher than those in freshly opened leaves of the plant from which the cultures were initiated (unpublished data). Because shoot tip culture *per se* does not eliminate GFLV (1), the success obtained in the present *in vitro* heat therapy experiment can be ascribed to the heat treatment itself rather than to metabolic disruption resulting from cell injury during explant excision. It is possible that the "RNA-dependent RNA polymerase" responsible for the manufacture of multiple copies of the GFLV genome, or some other virus-specific enzyme, may be completely inhibited at 39°C while the enzymes responsible for cell growth and division in the grapevine meristematic tissues may be only slightly inhibited. Knowledge of the exact mechanism of GFLV elimination through *in vitro* heat therapy will have to await a better understanding of the molecular biology of GFLV multiplication.

While the results presented here on the elimination of GFLV by *in vitro* heat therapy agree with those of a recently published report (1), our results concerning the elimination of grapevine leafroll by this method are at variance with that report. None of the tips taken from our heat-treated leafroll-infected grapevine tissue cultures yielded plants which were clearly leafroll-free. It is not clear from the previous report

how long the authors exposed their *in vitro* cultures to their heat therapy regime. Possibly the duration of treatment was longer than our 113 days. The authors also used shoot apices 1 mm in length while we used 2 mm shoot tips. This latter consideration and their use of different grapevine cultivars may be important in accounting for the differences between their results and ours. We are assuming that the leafroll disease initially present in their grapevines was the same as that present in ours. Any discussion of grapevine leafroll disease elimination is necessarily highly speculative, however, as the causative agent(s) has not yet been definitely identified. While it has been variously reported to be a potyvirus (21) or a closterovirus (7,17), no conclusive evidence has yet been presented that any specific type of virus can be regarded as the sole causal agent of grapevine leafroll (3). This disease is obviously complex and, until highly sensitive biochemical or immunochemical procedures become available to replace symptom expression as a diagnostic tool, the process of indexing to determine the success of eradication treatments must be considered to yield only tentative results. While symptom expression is useful in determining that a given treatment was not successful, more rigorous tests are needed to support a claim that the disease has been eliminated.

A different approach to in vitro virus eradication in plants is to include in the nutrient medium a chemical with a demonstrated ability to prevent virus replication. In order to be useful in generating virus-free shoot tips, the chemical must be effective at a concentration which does not cause phytotoxicity.

The first compound tested in this study, DHPA, has been reported to inhibit the replication *in vitro* of several animal DNA and RNA viruses (6). This compound was relatively nontoxic to animal cell cultures. For example, a concentration of 600 μg ml^{-1} was required to reduce the proliferation of mouse L-929 cells by 50%. When cultures of *V. vinifera* 'Limberger' infected with grapevine leafroll were exposed to this drug, however, only a few survived the treatments with 30 mg l^{-1} or more (20). At concentrations as low as 10 mg l^{-1}, this drug inhibited shoot proliferation significantly and caused some mortality. The data in Table 2 indicate that most of the shoot tips produced at concentrations of 10 and 15 mg l^{-1} DHPA were still infected. The remainder are still of uncertain status.

Vidarabine is another nucleoside analog which has been shown to possess broad-spectrum antiviral activity *in vitro* (4). At the concentrations tested this compound was ineffective in generating leafroll-free shoot tips (Table 3). Concentrations higher than 20 mg l^{-1} tended to be phytotoxic.

The third compound tested, ribavirin, has been demonstrated to act against both animal and plant viruses (8,9,13). It has been used to regenerate virus-free plants from cucumber mosaic virus- and potato virus Y-infected tobacco explants (2) and has been shown to delay the onset of grapevine leafroll symptom expression (20). The data from our experiment combining ribavirin treatment and shoot tip culture suggest that this form of *in vitro* chemotherapy may yield leafroll-free grapevines (Table 4). Plants regenerated from the ribavirin-treated cultures have been grown in the greenhouse for approximately two years and several combinations of treatment duration and drug concentration presently appear to have yielded leafroll-free shoot tips, based on symptom expression. Because there is no herbaceous host which can be used for leafroll indexing, however, and in the absence of appropriate immunochemical test methods the present results must be interpreted with the utmost caution. It is possible that ribavirin simply exerted a virostatic effect. This, in combination with the excision of small shoot tips, might have resulted in tips containing very few infectious agent particles. Their concentration might eventually increase to a level inducing disease symptoms.

Relatively little progress has been made in the eradication of virus diseases through *in vitro* chemotherapy since the 1950s when potato tissue cultures were freed of potato virus X with malachite green (18) and tobacco tissue cultures were freed of potato virus Y with 2-thiouracil (11). The problem lies mainly in identifying compounds which can act selectively against the virus while leaving the host cell metabolism relatively unaffected. In the early days, the problem was compounded by the limited selection of therapeutic chemicals available. This situation has now greatly improved as more and more antiviral agents are being identified. In addition chemicals with antiviral activity are being intensively studied to determine which chemical moiety is responsible for the therapeutic properties. Such structure-function analyses often lead to the synthesis of artificial analogs with even greater antiviral activity than the parent compound.

It is unlikely that any single drug will prove to be capable of inhibiting all of the viruses causing serious economic losses in the major horticultural crops. It is more realistic to attempt to identify drugs which are each effective against one or a few economically important viruses. The broad-spectrum antivirals are the candidates which need to be screened first, because of their greater potential. The interferon system which operates in animal cells possesses very broad antiviral activity and a similar system may exist in plants (19). Whereas the interfer-

ons are extremely expensive products, polyinosinic acid•polycytidylic acid, a very potent inducer of interferon in animal systems, is much more affordable. Experiments are in progress at Saanichton to determine whether poly (I)•poly (C) treatments can be used in combination with shoot tip culture to generate virus-free grapevines.

There are numerous reasons, mentioned throughout the text, why *in vitro* virus eradication techniques should become important adjuncts to virus indexing and eradication programs. Tissue culture methods, already of great importance in the mass propagation of stock plants, would then have even further impact on commercial horticulture.

ACKNOWLEDGEMENTS

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PROPAGATION: FOG NOT MIST

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Imagine a test tube environment the size of a greenhouse. An environment that guarantees zero transpiration loss, but that maintains a rooting medium that is light, fluffy, airy and not water-saturated. Recent improvements in fog system technology now make such an environment possible. The rooting zone is not overwet so there are much fewer disease problems

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and higher density planting is possible. Plants are not stressed, so they can tolerate more sunlight and higher temperatures and therefore root faster. But of more importance are the yields that can be achieved — virtually 100% yields with even hard-to-root species. Very large cuttings can be rooted without the need for air layering. This paper describes the hardware of one type of fog system, its applications in greenhouse microclimate control, and the difference between intermittent mist and continuous fog for use in propagation.

Description of Fog System. There are many methods of atomization, but very few are suitable for use in fog systems for greenhouse microclimate control. Spinning-type atomizers, for example, when rotated at high enough speeds, will produce droplets in the fog size range but the hardware becomes too expensive for any large scale application. Air jet atomizers are also capable of producing fog droplets but the energy requirements are 10 to 20 times greater than direct pressure atomizers.

Direct pressure mechanical atomization is the least energy consuming and the most practical in terms of hardware requirements for use on a large scale. Figure 1 shows a schematic which outlines the basic components of a fog system which utilizes this method for producing droplets in the desired size range.

At the heart of the system is the fog nozzle which is able to atomize water into microscopic water droplets. The nozzles operate under high pressure and the system therefore requires a high pressure pump. Due to the extremely small orifice size in the nozzle, extensive filtration is necessary to prevent possible nozzle clogging.

The fog nozzles are contained in PVC lines evenly spaced in the area to be fogged. A stream of water is forced to exit under high pressure from the small nozzle orifice. The high velocity stream impacts upon a pin placed over the center of the orifice and is shattered into extremely fine water droplets which make up the fog. The water droplets have a diameter about 1/10 that of a human hair. In terms of numbers, 95% of the droplets are less than 20 microns in diameter, almost identical to the drop sizes which occur in natural fog.

When the water source is not city water, it is treated with a small amount of chlorine to prevent slime-forming bacteria which could occur inside the nozzle orifices. Larger systems use a pre-filter, such as a sand filter, just downstream of the chlorine injection to trap any relatively large sediment or any particulates which may be formed when chlorine reacts with iron and other minerals in the water.

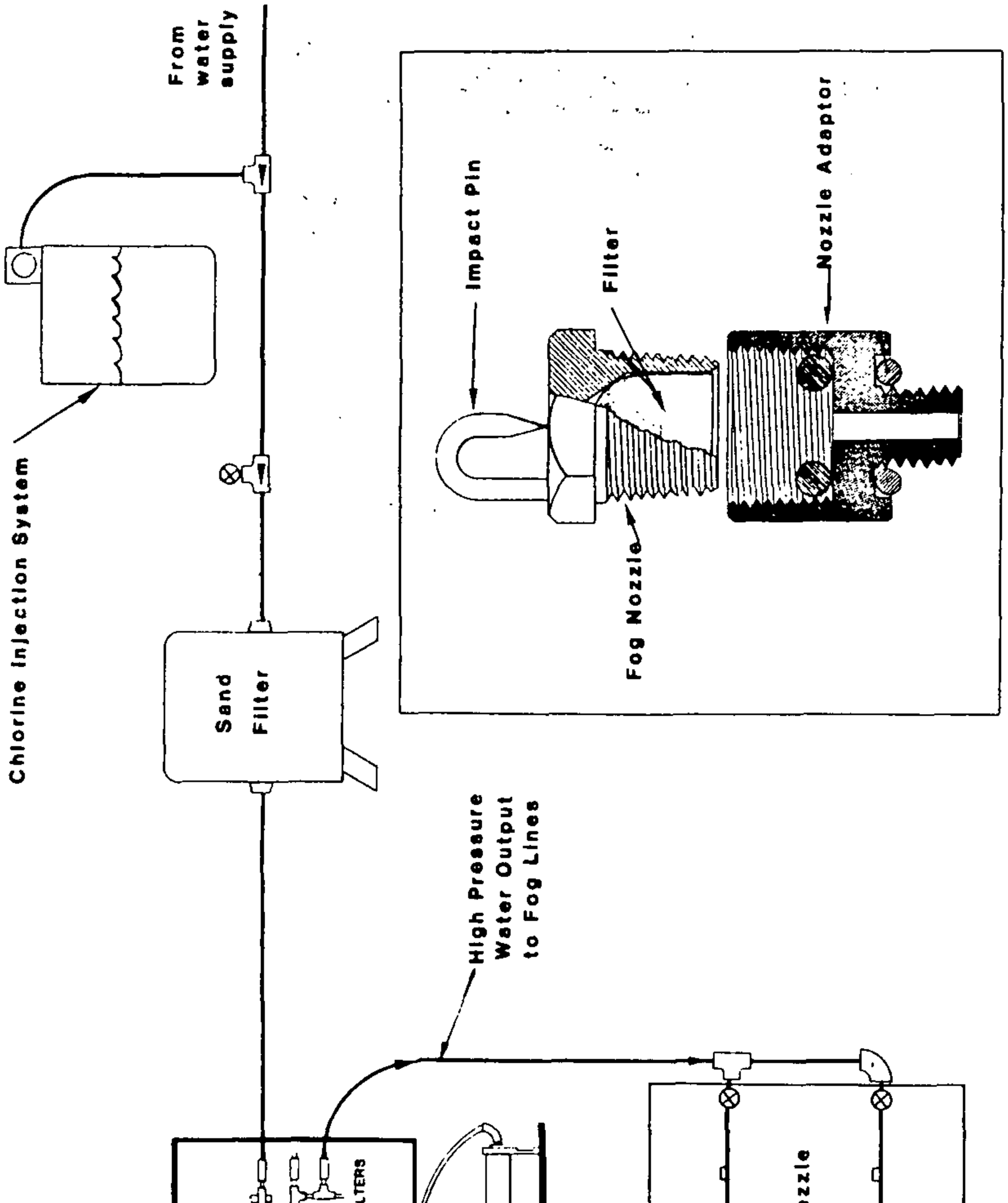


Figure 1. Fog system schematic.

The water is then routed to the main filtering and distribution manifold. It is filtered on the low pressure side of the manifold through a 10 micron cartridge-type filter after which it flows into the high pressure pump. The water exits the pump under a pressure of 600 psi and is filtered again through a high pressure cartridge filter. It is then sent through feedlines to the area to be fogged. The water is filtered one last time through a filter located at the back of each fog nozzle.

Fog vs. Mist in Propagation. Figure 2 compares the drop sizes produced by a high pressure mist system and by a fog system. Both views are enlarged approximately 150 times to show the individual droplets in the fog and in the mist. It should be noted that both systems were operated under the same pressure, about 550 psi, to achieve this comparison.

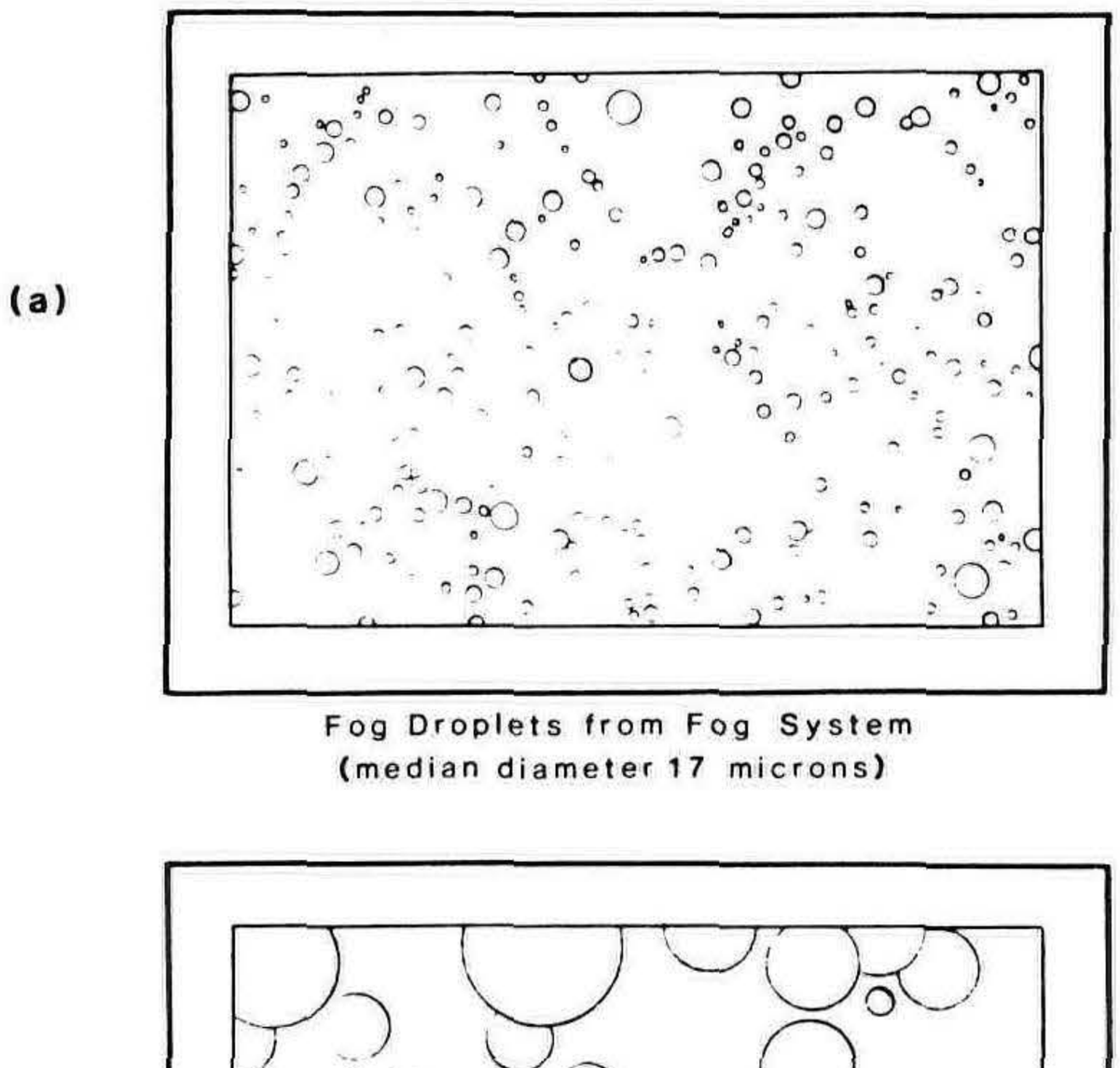


Figure 2. Fog droplets vs. mist droplets.

It is obvious from the figure that the droplets in the fog are many times smaller than those in the high pressure mist. The significance of the particle size is quite simple to see. Any droplet larger than about 35 microns will settle out and cause overwetting of the rooting medium. This may mean rotting, leaching of nutrients, and lack of sufficient oxygen reaching the roots; all factors which lower yields. On the scale at the bottom of Figure 2, 35 microns is but 3½ of the tiny divisions, and almost all of the mist particles are considerably larger than this.

All of the fog droplets are smaller than 35 microns, in fact most of them are smaller than 10 microns. Fog droplets float indefinitely and do not settle out. It takes only 10 sec for a 100 micron particle to reach the ground from 10 feet. By comparison, in still air, a 10 micron fog droplet would take 17 min to fall this distance. In practice, any slight air movements will keep the fog droplets suspended.

Typically, mist systems are operated under pressures of about 125 psi or less and the droplets are even larger than those shown in Figure 2(b).

Many advantages of fog over mist result from the fact that fog will remain suspended in the air while mist will not. For use in propagation, a fog system produces a visible fog in the area surrounding the propagating benches. This keeps the relative humidity of the propagating environment right at 100%, meaning that the air is saturated with water vapor and there can be no evaporation. The transpiration loss from the cuttings is virtually eliminated.

Equally as important is the fact that while maintaining a 100% relative humidity condition, the fog does not overwet the leaves or the rooting medium. Fog nozzles use about 25 times less water than mist nozzles and thus the rooting medium and the root zone in a fog house remain relatively dry and oxygen is readily available for root development. This produces an ideal environment for propagation of cuttings, as well as seedlings and tissue culture.

An interesting point to note is that although a dense fog is visible in the house, it does not act as a shade in any way. Light intensities at the crop level have been shown to be the same with or without fog present.

The result of eliminating loss of moisture through the leaves, while allowing oxygen to freely flow in the root zone, is that the cuttings are under much less stress. Growers have reported rooting times shortened, larger cuttings started without leaf loss, less disease, and increases in yields of rooted

cuttings from 40% under mist to 99% under fog in some species.

Other Applications. In addition to providing an optimum propagating environment, a fog system can be used for complete climate control in greenhouses and shadehouses. It can be used for cooling, for foliar feeding, for fungicide/insecticide applications, for supplemental heating, and for freeze protection.

Foliar feeds, provided they are liquid or water soluble, can be put directly through the fog system. With the entire house sealed off, the solution containing the foliar feed will form a dense fog. The fog penetrates the foliage resulting in an even application throughout each plant, the undersides as well as the top. Liquid fungicides or insecticides can also be applied directly through the system.

Fog has been used extensively for its cooling properties, both in fan ventilated and naturally ventilated houses. In the cooling mode, the fog application rate is controlled so that all the fog evaporates. This differs from the propagation mode in which a visible fog is present in the house.

The amount of cooling which can be achieved depends on the relative humidity of the outside air. Up to 40 degrees of cooling has been demonstrated with outside air temperatures of 115°F and 10% relative humidity. Undoubtedly, this is an extreme case. For typical summer conditions, 20 degrees of cooling is common.

Fog System Design. The mode of operation for the system, such as propagating, cooling, etc., determines the on and off cycles for the fog nozzles. For example, in the propagating mode, the nozzles would operate about 90% of the time during a sunny afternoon in order to maintain a 100% relative humidity condition. At night the nozzles may operate only 5% of the time for the same effect. Thermostat/humidistat controls and repeat cycle timers allow a wide range of versatility to achieve the desired fogging effect.

In naturally ventilated houses, fog lines are usually placed over the aisles, spanning the length of the house. In a house with roof vents and side vents, the fog produced by each fog nozzle evaporates, cooling and humidifying the air, which, as a result of its increased density, falls downward into the growing zone. The air can then exit through the side vents. This sets up a circulation which draws outside air in through the roof vents, as shown in Figure 3.

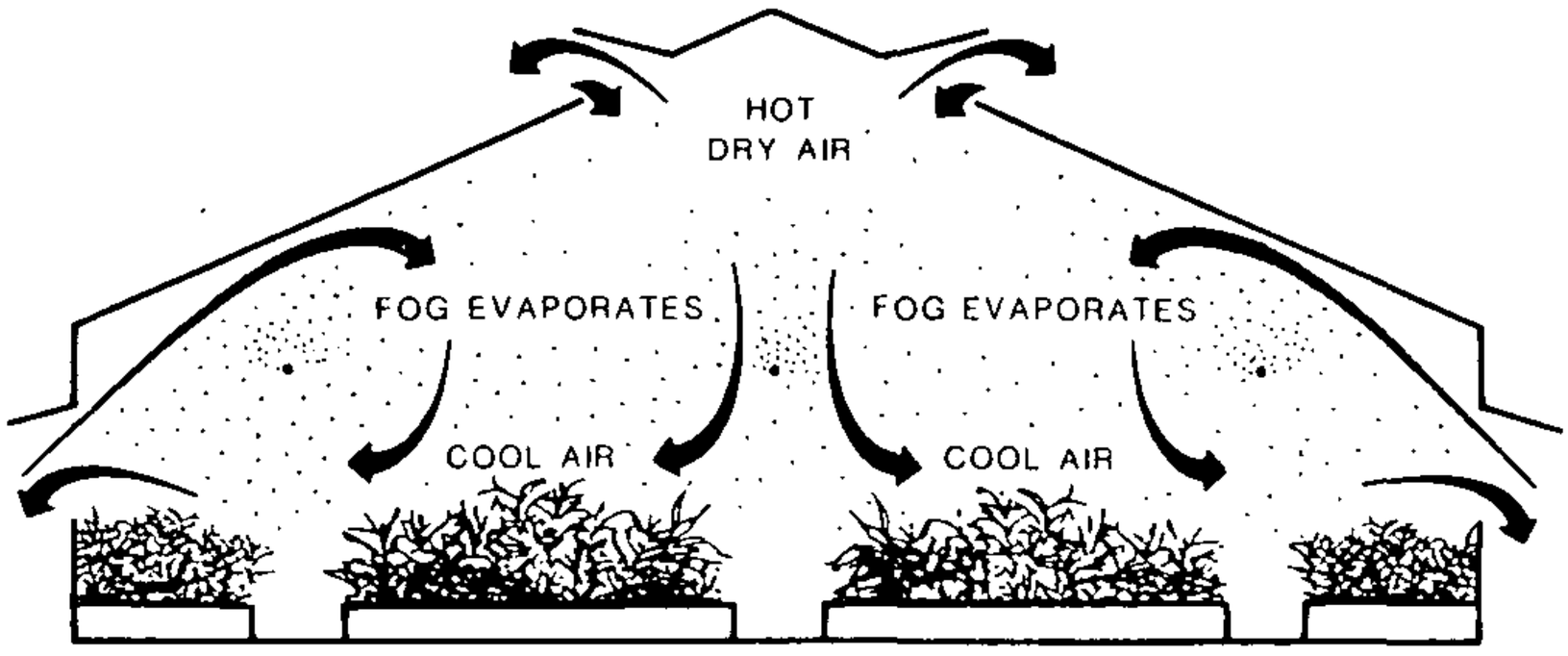
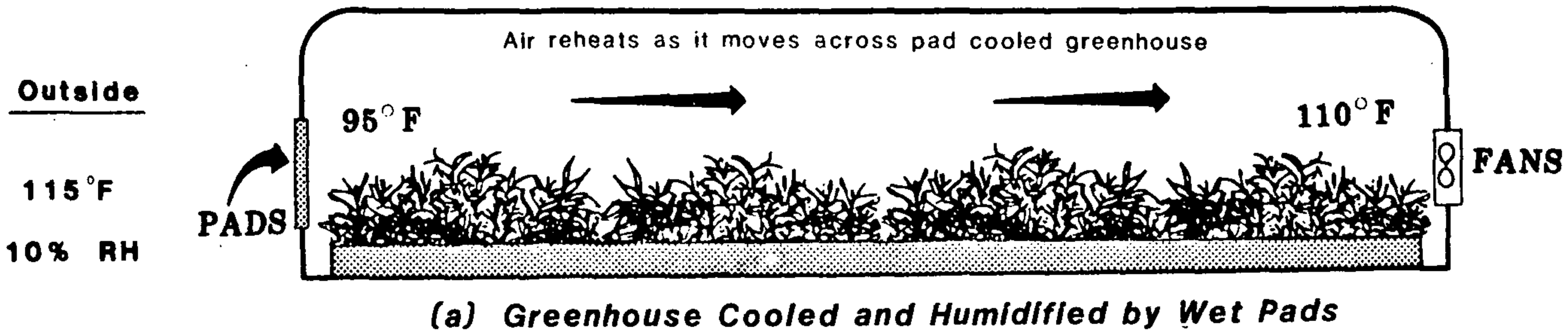


Figure 3. Cooling and humidifying without fans using a fog system.

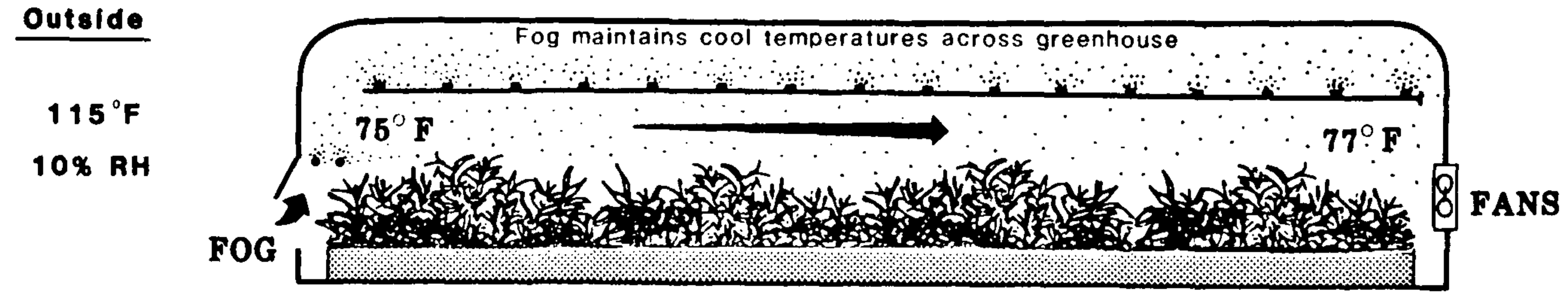
For proper ventilation in propagating, the naturally vented house should have openable vent space equivalent to at least 10% of the total floor space in the house.

A fog system is also very efficient for achieving an ideal propagating environment in a fan ventilated house; however, the design is slightly different from that of a naturally vented house. In the fan ventilated design, a dense array of fog nozzles is placed at the end of the house opposite the exhaust fans, i.e. the intake end of the house. The purpose of these intake fog lines is to initially cool and humidify the outside air as it enters the house. The intake fog lines provide the bulk of the humidification, but in addition, fog nozzles are placed in overhead lines which run down the aisles, spanning the length of the house. The purpose of these overhead lines is to prevent drying of the air as it is drawn through the house by the exhaust fans.

Figure 4 shows a comparison between a greenhouse which was cooled and humidified by a fog system and one which was cooled and humidified by a wet pad and fan system. The measurements were taken simultaneously on a dry summer day in the Arizona desert. The pad and fan system cooled the air from 115°F to 95°F as measured just inside the pad. The relative humidity was increased from 10% outside to 32% just inside the pads. The temperature, however, increased as the air was drawn toward the fans. The air temperature had risen to 110°F after the air had traversed the house, due to the solar reheating.



(a) Greenhouse Cooled and Humidified by Wet Pads



(b) Greenhouse Cooled and Humidified by Fog

Figure 4. Greenhouse environment control: wet pads vs. fog.

In the fog cooled greenhouse, the microscopic fog droplets proved much more efficient as an evaporative cooling system and were able to cool the air down to within a few degrees of the outside wetbulb temperature. The incoming air was cooled from 115°F to 75°F at the intake end of the house and the relative humidity was increased from 10% outside to 85% inside.

Unlike the wet pad system, the air in the fog cooled greenhouse reheated very little as it was drawn through the house, since overhead fog nozzles were situated down the entire length. As the air was drawn through the house, the humidity increased further — up to 100%. The air was able to reheat only 2 degrees between the intake end and the fan end, in comparison with 15 degrees of reheating in the pad and fan house.

A further point worth considering is the fan ventilation rate in the pad-cooled house versus the fog cooled house. Typical pad and fan systems are designed for an air flow rate of 1 air change per minute, meaning that the volume of air in the house is completely replaced with outside air (pulled through by the exhaust fans) after 1 minute. The fog system is typically designed for 1 air change per 2 minutes, only half the ventilation rate required in a pad and fan system. Thus in a house requiring 2 fans for a pad and fan system, only 1 of these fans need be run if a fog system is installed.

Supplemental Heating and Freeze Protection. Fog is a very good reflector of heat energy and growers and horticulturists have long recognized that a cloud cover throughout the course of a night will keep minimum temperatures higher than would be the case if no clouds were present. For this reason, another application of the fog system is in supplemental heating and freeze protection of crops during winter months.

Fog acts in precisely the same way as a natural cloud since fog is nothing more than a cloud at ground level. A visible fog covering the growing benches in a greenhouse will trap in and evenly distribute the heat supplied by any heating system. Without fog, most of the heat produced by heaters rises to the top of the house and is lost by conduction through the roof.

Another advantage with fog is that thermostats can be set at the same temperature as the minimum desired plant temperatures; they need not be set 5° to 10° above this temperature, as is sometimes done in practice. The reason for this is that in a fog house, the temperature of the air is also the dewpoint temperature. If a leaf or plant tissue begins to cool below this temperature, condensation takes place on the plant,

and a large amount of heat is released (known as the latent heat of condensation). The result is that the plant temperature will not cool below the dewpoint, which is the same as the air temperature in the house. Fog is also a much better conductor of heat than is dry air. In effect, for a given thermostat setting, the plant temperatures will remain 5° to 10° warmer in a house filled with fog than in one with no fog.

Inherent in using fog as a supplement to heaters is the fact that the relative humidity is kept at 100%. In a house heated without fog, the relative humidity drops substantially as the temperature rises.

For use in cold protection, the fog need not be used in conjunction with heaters, for the system will work alone as a freeze protection mechanism in greenhouses, shadehouses, and outdoor areas. By running the system continuously throughout the night, a dense blanket of fog can be formed and maintained even in an outdoor area. The fog acts as a reflector of the infra-red heat radiation which normally escapes from the ground and all solid objects during the night. The blanket of fog traps the heat and keeps temperatures from cooling as rapidly as they would during a clear sky condition. Up to 11°F protection has been shown in an outdoor application, e.g., the ambient air temperatures dropped to 21°F while leaf temperatures inside the fog area remained at 32°F. Even more protection can be expected in greenhouses and shadehouses due to easier containment of the fog in the desired area.

CONCLUSION

Fog systems differ considerably from mist systems. A fog system produces droplets small enough to remain suspended in the air, resulting in a 100% relative humidity environment assuring zero transpiration loss, but without overwetting the plants or the rooting medium.

The optimum propagating environment of ample root zone aeration and zero transpiration loss causes much less stress on the young plantlets. Increased yields, less disease, larger cuttings rooted, and shorter rooting times have been reported by growers propagating in a fog environment.

ROOTING CONIFER CUTTINGS WITH A FOG SYSTEM

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Crown Zellerbach has been rooting conifer cuttings, particularly western hemlock (*Tsuga heterophylla* [Raf.] Sarg.), in a fog system since 1976. Crown's interest in the rooting of cuttings stems from ongoing research efforts in tree breeding, genetics, and physiology. For these types of research, vegetative propagation is an essential step. Grafting has been favored by foresters for vegetative propagation but grafting has the limitations of possible graft incompatibility and of rootstock influence on scion performance.

Rooting success of western hemlock cuttings has been reported from zero to near 100%. Sorenson and Campbell (5) reported 75% rooting using one-year old seedlings as donors. Rooting from juvenile donor plants (before onset of flowering) has been reported at 68% by Foster, *et al.* (3) and up to 95% by Boyd (1). Brix and Barker (2) found cuttings from mature (42 to 150 year old) donors to root at 43%. Foster, *et al.* (3) found cuttings from mature donors to root at about 34%.

Rooting success has not been universal. An appropriately controlled environment is critical to success. In 1975, Brix and Barker (2) summarized a number of experiments in a concise report, "Rooting Studies of Western Hemlock Cuttings", which remains the best single source on the subject. The studies reported covered time of cutting collection, rooting hormone trials, and rooting systems, among other topics. Brix and Barker (2) suggest that an appropriate rooting environment was a cold frame, shaded from direct sunlight, with no mist and no heat. They were working in Victoria, British Columbia, a somewhat different environment than the mid-Willamette Valley of Oregon. Brix and Barker obtained equally good results by enclosing a bench in plastic with periodic mist. Bottom heat showed no benefit. Our experience suggests a maximum high temperature of 28°C for successful rooting. There is evidence that photoperiod control and CO_2 enrichment are beneficial to rooting success in some hard-to-root cuttings (4,6). Boyd (1) suggests that high atmospheric humidity is essential and that rooting success in western hemlock is directly related to the degree of environmental controls.

In 1976, Crown Zellerbach set up the first iteration of our current system. In 1979, after a complete failure in 1978 due to excessive temperatures, the system was redesigned. Wood

frame, vinyl-covered, chambers are set inside a greenhouse. Temperature inside the greenhouse is controlled by heaters, evaporative coolers, exhaust fans, and a movable side wall. There is no bottom heat. Humidity is controlled with fog or ultra-low volume mist nozzles. Water and CO_2 enriched air are mixed at the nozzle head. Separate lines for water and air are regulated by parallel solenoids and controlled with an interval timer. The photoperiod is extended to 18 hours. This system, with minor changes, is still in use.

Our results, since 1979, have been consistent for western hemlock rooting. Juvenile donor material roots at 60%. Mature donor material roots at 35%. Cyclical propagation improves rooting. There are differences among clones in rooting ability. The system as described has been used with success to root Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) and red alder (*Alnus oregona* Nutt. — Syn. *A. rubra* Bong.).

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VOICE: In computer controls for greenhouse environments can you have a control for the humidity without bringing in cold air?

HUGO WILDSCHUT: The answer is yes. A program can be written to cover any controls desired. It is a matter of components mostly. Whatever sensors are necessary can be put in.

IRENE BURDEN: Can these computer units be used satisfactorily in the very humid conditions in a greenhouse?

HUGO WILDSCHUT: Yes, certain units are hermetically sealed and will work well in very high humidity situations.

VOICE: What is the cost for the greenhouse computer units?

HUGH WILDSCHUT: From $300 to $2000, depending upon the complexity of the controls.

VOICE: What is the percent nitrogen in the Strawdust growing mix?

DICK TEUFEL: It has 1.34% actual nitrogen on a dry weight basis.

VOICE: How long does the Strawdust last in use?

DICK TEUFEL: We have had plants growing in it for 3 to 4 years and still have good aeration.

VOICE: How does Strawdust compare with sawdust as a soil amendent, pricewise?

DICK TEUFEL: It is more expensive than sawdust, but the Srawdust has a fertilizer component which makes it quite competitive. Strawdust current price is $16.50/cu. yd.

LES CLAY: In Wilbur Bluhm's cost studies for cuttings, he found that collecting cuttings away from the nursery was less costly than collecting at the nursery. How is this accounted for?

WILBUR BLUHM: This is due to maintenance costs of mother stock blocks at the nursery, not found when collecting away from the nursery.

VOICE: In your fog systems how much of a drip problem do you have from the nozzles?

TIMOTHY PRESS: If the pipe system is exactly horizontal and if there is a fog nozzle placed at the very end of the line, we practically eliminate any drip.

VOICE: Early fog systems had the problem of nozzles orifices clogging. How is this handled now?

TIMOTHY PRESS: It depends on the water source. If the water is high in calcium or iron salts it can be pretreated with either a chemical sequestrant or an electrostatic type treatment, either of which will hold the salts in solution so there is no scale build-up.

VOICE: What is the cost of operation of these fog units?

TIMOTHY PRESS: In fogging up to 7,000 sq. ft. the motor is a 1½ h.p. unit so it uses about 1½ kilowatts and at 5¢ per kw hr it would cost 7½¢ per hr to operate if run continuously, which you would do on a hot afternoon.

VOICE: What amount of cooling can you obtain with fog in a very humid environment as compared to a dry environment?

TIMOTHY PRESS: In theory you can always cool the air down to what is known as the "wet bulb" temperature, which varies considerably in different areas. In a very humid area, as southern Florida in the summer, the wet bulb temperature is about 80°F, so cooling only to 80°F can be obtained, but if ambient temperature is 90°F, 10° of cooling can be obtained.

TISSUE CULTURE PROPAGATION OF SELECTED MATURE CLONES OF *LIQUIDAMBAR STYRACIFLUA*

ELLEN SUTTER

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Liquidambar styraciflua (sweetgum) is a desirable tree for the urban landscape. It possesses several qualities such as striking fall color, a pleasant form, attractively shaped leaves, and an ability to provide shade, which have made it increasingly popular as a street tree. However, sweetgum has several disadvantages which must be considered when selecting it for the urban landscape.

When sweetgum is grown from seedlings, the trees exhibit great variability in form and color. It also has an invasive root system that necessitates extensive and costly sidewalk repairs. Finally, grafting clonal scions onto seedling rootstocks as a means of overcoming variability is an expensive procedure, and results in higher costs for the growers, and consequently for the consumer.

Considering the popularity of sweetgum, it would be desirable to obain superior selections and propagate them clonally. However, sweetgum cuttings do not root easily (1) and thus must be produced by budding to maintain clonal selections. Not only is budding expensive, when scions are budded onto seedling rootstocks the rootstocks continue to impart some variability to the entire tree. Nonetheless there would be a value to budding, even if expensive, if a valuable rootstock could be identified and if it could be clonally produced.

Several trees in the San Francisco Bay area of California have recently been identified that possess superior fall color, delayed leaf drop, and non-invasive root systems, all of which would contribute favorably to an improved clone of *Liquidambar sytraciflua*.

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Since these trees are all mature, ranging from 20 to 30 years old, they are difficult to root from cuttings. A possibility was to try micropropagation, a technique which has been used to propagate trees that are difficult to propagate by conventional methods such as cuttings and layering (2). For many tree crops, micropropagation has been used most successfully on explants in the juvenile stages of growth, since mature woody plants often do not respond favorably in culture (5,7).

The objective of this study was to propagate selected, mature clones of *Liquidambar styraciflua* by micropropagation. In this way clonally propagated material could be developed from superior mature individuals without the necessity of grafting.

MATERIALS AND METHODS

Both seedlings and mature trees were used in this study. One-year-old seedlings were donated by Saratoga Horticultural Foundation, Saratoga, California. Material from mature trees was collected from selected trees in the San Francisco Bay area.

Lateral buds were used as explant sources. Explants were surface-sterilized by a series of steps. Stems were washed in a dilute soap solution, and then dipped for 30 seconds in 5% Amphyl. A 20-minute wash in 20% laundry bleach to which 0.1% Tween 20 had been added followed, with a second wash (5 minutes) in 20% laundry bleach. The shoots were then rinsed four times in sterile, distilled water. Buds were excised from the shoots and placed in culture.

For the nutrient medium, both Linsmaier-Skoog (LS) (3) and Woody Plant Medium (WPM) (4) were used, without additional hormones, or with benzyladenine (BA) at 0.2 or 1.0 mg/l. Cultures were incubated at 25°C for a 16-hour photoperiod under 60 $\mu Em^{-2}sec^{-1}$.

RESULTS

Growth of seedling explants in vitro. Initial work was performed on explants from seedlings because we found it difficult to adequately disinfest mature material during the autumn when the study began. Excessive rains had resulted in large amounts of bacterial contamination on explants.

Explants from seedlings grew well on WPM. Those on LS, at all hormone concentrations, turned brown and became necrotic. Buds on WPM elongated after 4 to 6 weeks in culture. Multiple shoots appeared on plants in WPM medium containing both 0.2 mg/l BA and 1.0 mg/l BA, but those on the higher concentration of BA were rosetted and did not elongate even

after 2 months. Consequently the medium used to propagate shoots initially was WPM with 0.2 mg/l BA.

An experiment was conducted to determine the optimum salt concentrations of the various components of WPM. All stocks were prepared at ⅓ and 3 times the original concentration. Shoots that had been produced on the original WPM formula were placed on these different media for 4 weeks. There was no improvement in growth of the shoots on most of the different media compared to controls. The only change in salts that resulted in more vigorous growth than the control was ⅓ the concentration of $CaCl_2$. Consequently the revised medium consisted of WPM with ⅓ concentration of $CaCl_2$ stock and 0.2 mg/l BA.

Single shoots, approximately 0.5 cm tall, produced on the modified WPM, were removed and placed on different media for rooting. Of the 5 treatments used (Table 1), WPM with 0.5 mg/l indolebutyric acid (IBA) and 1.0 mg/l IBA were the most effective in producing high percentages of rooting (Table 1). At higher concentrations of IBA, many shoots turned brown and died. WPM with 0.5 mg/l IBA was selected as the medium of choice for root induction since 1.0 mg/l IBA produced excessive amounts of callus. The plants were vigorous and were transplanted to flats in humidity tents in the greenhouse without difficulty. After 1 month in the greenhouse, plants were transferred to pots (Figure 2).

Table 1. Effect of different IBA concentrations on root formation of *Liquidambar styraciflua* shoots regenerated *in vitro*.

	Root formation (percent of plants forming roots)	
Treatment	After 3 weeks	After 6 weeks
0.2 mg/l IBA	31	77
0.5 mg/l IBA	22	78
1.0 mg/l IBA	40	78
2.5 mg/l IBA	0	25
No hormone	0	0

Figure 1. Tissue culture derived plant of *Liquidambar styraciflua* 2 months after transfer to greenhouse. Explant source was from a 1-year-old seedling.

Growth of explants from mature plants in vitro The best medium selected using seedlings as source plants was used for incubating explants from mature plants of sweetgum. Shoots were taken in early spring just before bud break. The shoots were forced indoors and all explants were taken from actively growing buds on the upper 3 to 4 in. of the shoot. The buds were excised from the stem before being placed in culture.

It was critical that the buds be transferred every 3 to 4 days during the first 2 weeks *in vitro*. Buds that were transferred weekly and then at 3 to 4 weeks intervals did not grow as vigorously as those transferred more frequently.

Most shoots grew well but there were obvious differences in response of different genotypes. One genotype remained stunted throughout the study, whereas the other 3 genotypes grew rapidly and formed multiple shoots.

Single shoots were detached from the cultures and incubated on rooting medium determined previously. The rooting percentages for shoots derived from mature trees were lower than for those derived from seedlings and were related to genotype (Table 2). The 3 genotypes that grew vigorously also produced the most prolific roots (Figure 2).

Table 2. Effect of genotype in mature trees on rooting of *Liquidambar styraciflua* shoots regenerated in vitro after 4 weeks on rooting medium.

Genotype	Rooting (percent of plants forming roots)
A	20
C	40
D	40
E	100

DISCUSSION

It is possible to propagate complete plants from excised buds of mature specimens of *Liquidambar styraciflua* by micropropagation. The plant selections used in this study had not been able to be propagated by conventional methods previously. It was advantageous to determine the basal medium using seedling material grown in pots in a greenhouse because the buds were easily surface-disinfested and could be obtained in active growth when mature plants in the field were becoming dormant. The medium developed using seedling material was applicable to mature material although differences in responses among genotypes were noted. It has been shown for a variety of other material that there can be significant differences among cultivars in response to media (6).

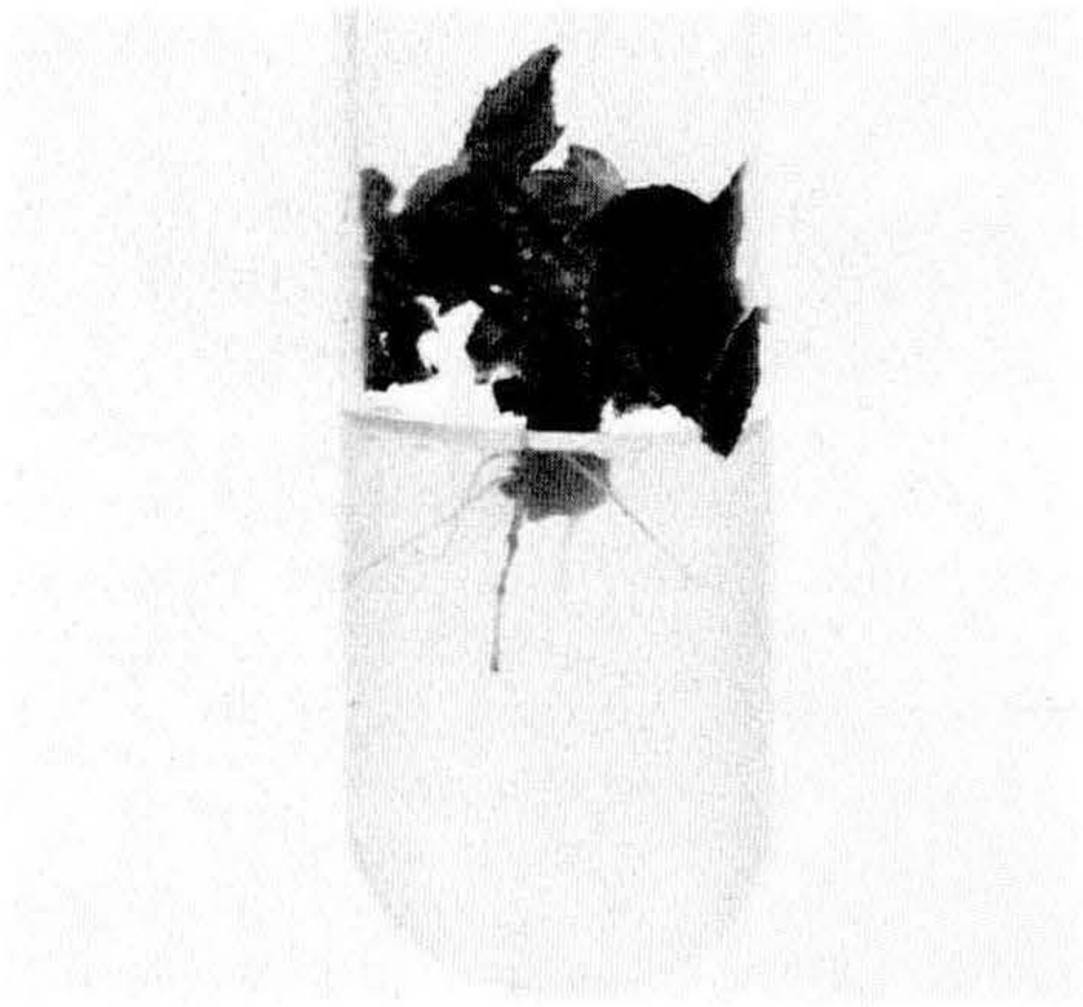

Figure 2. Complete plant of *Liquidambar styraciflua in vitro* derived from a mature plant.

The rooting percentage of mature material was lower than that from juvenile material but all genotypes could be rooted. Preliminary experiments with seedling material indicated that complete plants can be transferred to the greenhouse without difficulty.

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VEGETATIVE PROPAGATION OF *ACACIA ITEAPHYLLA*

BARRIE COATE

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In October, 1978, two especially attractive *Acacia iteaphylla* F.J. Muell specimens (Figure 1) were observed in an insect tolerance test planting at the Deciduous Fruit Field Station of the University of California in San Jose.

Since this species had proven to be comparatively resistant to Acacia psyllid, *Psylla uncatoides* Ferris & Klyver in these tests and the species has so many attractive characteristics, it was decided to attempt vegetative propagation of these especially attractive individuals.

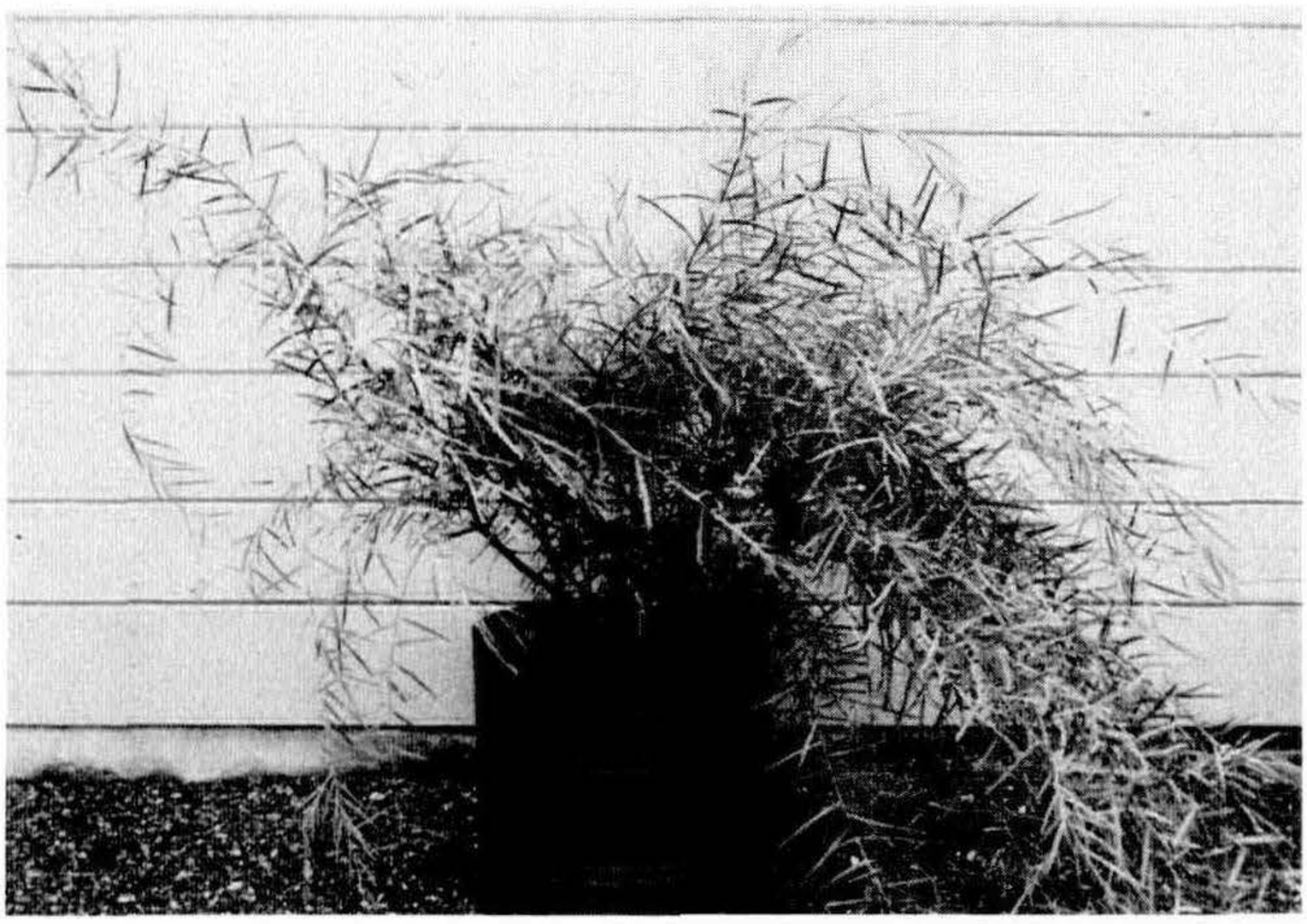

Figure 1. Appearance of *Acacia iteaphylla* cultivar.

On October 20, 1978, 3 to 4 in. long tip cuttings were collected and segregated into soft tips and semi-hard tip cuttings, each containing nine to eleven nodes, and placed in a greenhouse with 68° to 70°F bottom heat and intermittent mist at 5 sec every 20 min.

During these first trials, cuttings of one parent yielded significantly higher success than the other. The second clone has been dropped in subsequent trials.

During 1979 and 1980, plants of clone 78-60 were grown on in 1-gal, then 5 gal and finally into 15 gal containers. In order to create the desired stock plant condition, the following steps were followed:

January 19, 1982. Two 15-gal plants of 5 ft by 5 ft dimensions were placed in a heated plastic house and pruned to 18 × 18 in.

January 27 and February 3, 1982. Cut stumps and base of the trunks were painted with 500 ppm benzylaminepurine (BAP).

February 5, 1982. Latent buds were observed swelling along all old wood surfaces. A 20-20-20 liquid fertilizer was applied in sufficient quantity to drench soil ball.

March 9, 1982. Extensive sprout generation occurred.

March 24, 1982. Three to four inch terminal cuttings with soft terminal portions removed were pulled, with heels, from the old wood, dipped in Hormex #8, and stuck in a mix of 8 parts perlite and 1 part peat moss; 68° to 70°F bottom heat and a mist cycle of 5 sec in 20 min was provided.

April 20, 1982. A few leaves had dropped. The cuttings were judged to be rooting well at this point. The flat was moved to a plastic house without heat or mist. Hand watering was provided when considered necessary.

May 14, 1982. Ninety percent of the cuttings were judged to have excellent roots and top growth and they were potted to 2¼ in peat pots.

In summary, spring-collected heel cuttings from vigorous new wood near the ground produced healthy cuttings with excellent roots in 50 days (Table 1).

Subsequent work in late September, 1982, by Dr. Choong Lee, University of California at Davis, on this clone, using the same mother plants still in the greenhouse as a source of cuttings, produced similar results.

Table 1. Results obtained in the rooting of leafy cuttings of *Acacia iteaphylla*.

Clone #78-60	Clone #78-61	Type of cutting	No. of cuttings taken	Hormone treatment	Number potted	Date of potting	Percent rooting
Date Taken	Date Taken						
Sept. 20, 1978		Soft tips	98	Quick dip in 50% alcohol + Hormex #3 (IBA 3000 ppm in talc)	27	Dec. 28, 1978	28%
Sept. 20, 1978		Firm tips	89	Quick dip in 50% alcohol + Hormex #3 (IBA 3000 ppm in talc)	19	Dec. 28, 1978	21
	Sept. 20, 1978	Soft tips	49	Quick dip in 50% alcohol + Hormex #3 (IBA 3000 ppm in talc)	2	Dec. 28, 1978	4
	Sept. 20, 1978	Firm tips	45	Quick dip in 50% alcohol + Hormex #3 (IBA 3000 ppm in talc)	6	Dec. 28, 1978	13
Mar. 24, 1982		2nd cutting	88	Hormex #8 (IBA 8000 ppm in talc)	79	May 14, 1982	90

UNIVERSITY OF BRITISH COLUMBIA BOTANICAL GARDEN PLANT INTRODUCTION SCHEME — AN OPPORTUNITY FOR A NEW RELATIONSHIP BETWEEN NURSERIES AND THE PUBLIC GARDEN

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Abstract. A new plant introduction program has been launched by the UBC Botanical Garden. The program, P.I.S.B.G., is designed to increase diversity in commercially-available plants, provide new financial incentives for the nursery industry, provide for effective utilization of The Botanical Garden collections through research and development of new or recommended introductions, and provide a revenue source through royalties for the Garden.

Origin of the Program. All botanical gardens and arboreta are proud of the development of their collections which are correctly identified, accessioned, and documented as to source. Introduction of new material to the industry has been, at best, sporadic with a few exceptions. The usual method of introduction is by an ad hoc transfer of material from gardens in small quantities to a specific grower who has shown an interest in a particular item. There has been no development of a contract arrangement between public gardens and the nursery industry to provide for an orderly development of a successful introduction. The UBC Botanical Garden maintains a collection of 15,000 different kinds of plants and approximately 500 new accessions are added each year. The Garden has not been a major source of new material to the industry during its nearly 70 years of operation. This has been a source of some concern. Initial effort for introduction of new plants in the past 15 years have followed the usual ad hoc pattern. Past programs have resulted in sporadic and non-productive release of new materials. The Garden attempted to rectify this situation some four years ago when a committee was established to look at the whole question of how successful introductions could be best achieved from the Garden to the commercial industry.

The Garden has, as a basis, a wide diversity of plant material of known source, often wild-collected from indigenous sites as well as material received on exchange from specialized programs such as sponsored expeditions or through recognized institutional programs, such as the United States Department of Agriculture, the Saratoga Horticultural Foundation, and the Long Ashton Clonal Scheme of Great Britain. These plant collections form the basis for the display units, which, at UBC, are used for teaching, research and public

information. The wealth of material that is contained within the Garden collection was thought to be an excellent gene pool on which to do research and development through selection and testing procedures to achieve new material that would be appropriate for introduction to the trade.

In order to achieve a successful introduction program, members of the nursery trades association, public parks programs, government horticultural personnel, and landscape architects and architects were invited to participate in a selection process which would provide a rationale basis for selection of material for introduction into the nursery. This program, known as the Plant Introduction Scheme of the UBC Botanical Garden (P.I.S.B.G.), became a reality in 1981 and the first plants from this program were introduced to the trade in August, 1983.

Organization and Operation of the Program. The management of the program is vested in the Botanical Garden. There are three principal components of the PISBG program, each with advisory committees:

(1) Research and Development

(2) Plant Introduction and Release

(3) Administration

The research and development program is responsible for the analysis of the plant material that is being selected by the selection and evaluation committee. Effective methods of propagation and growing-on of the plant material are determined. An introduction display area has been established in addition to planting test material on landscape sites at the University. Proposed introductions are distributed to cooperator testing stations. The research and development program produces technical publications and information for the grower and the public-at-large.

The plant introduction and release program has a technical advisory committee, consisting of members of the commercial nursery industry. In addition, publicity and technical releases are developed by the Botanical Garden staff. A formal contract for the growing-on and release of the material has been established by the Botanical Garden with participator nurseries.

The P.I.S.B.G. has a general committee which advises on all aspects of the program and has two specialized committees, namely the Research Advisory Committee for the research phase of the program, and an Introduction and Release Committee, which serves as an effective liaison between the industry and the Botanical Garden.

The overall administration of the program is managed by the Botanical Garden and it is responsible for the development of outside contracts with funding and granting agencies.

Selection Process. The Botanical Garden staff makes a preliminary selection of plant material that may be considered by the general advisory committee for possible incorporation into the P.I.S.B.G. program. Following a further selection of these plants by the general committee, a wide variety of people in the horticultural industry are invited to spend a day at the Garden reviewing the plants that have been selected for possible inclusion in the program. These plants are rated on a scale from 1-10 and the following criteria are assessed: (1) sale to public authorities; (2) sale to retail outlets; (3) sale from retail outlets; (4) use by local authorities; (5) use by landscape architects; (6) use by contractors.

Each examiner is asked if the plant is unique within the B.C. nursery industry and to justify response. Each of the plants are rated and an overall potential, based on a rating of 1 to 10, is then determined for the plant. Additional comments may be added by the evaluator.

The review of the plants, usually 10 to 12 in number, are then correlated. The General Advisory Committee reviews this information and makes a recommendation for those plants that should be placed in the PISBG Scheme.

Research and Development. The plants selected for the P.I.S.B.G. Scheme then undergo a series of propagation and growing-on trials. This program is carried out in the Nursery component of the Botanical Gardens and follows usual research techniques. The Research Advisory Committee periodically reviews and evaluates the research program.

Testing and Evaluation. Plants from the program are sent to eight cooperating research institutional test stations. These test stations are located in Summerland and Prince George, British Columbia; Edmonton and Brooks, Alberta; Morden, Manitoba; Hamilton, Ontario; Aurora, Oregon; and Saratoga, California. They represent various climatic growing regions and soil types. The material is sent for evaluation over a set time period. Cooperating research institutional test stations keep detailed records based on a set of criteria established by the P.I.S.B.G. to determine the suitability of that plant for that growing zone. At the same time material continues to be tested and evaluated at the Botanical Garden at the University of British Columbia.

Release of New or Recommended Introductions. An Introduction Release Committee has been established to determine the appropriate mechanism for release of material propagated

by the Botanical Garden. Normally, material is bulked up by the Botanical Garden in 1 gal containers in lots of 50 plants to a unit. Participator nurseries are invited to submit application to participate in the program and determine how many units of the propagated material they wish to have for stock plants. A contract is drawn up between the Participator Nursery selected and the Botanical Garden. Each plant purchased must provide a minimum of 20 replicates within the 2-year period.

The aim of the program is to provide a minimum of 10,000 plants for the commercial market in a 2-year period. This is a one-time introduction to the industry, although some additional cutting material from the stock plants can be made available from the Botanical Garden. It is anticipated that a minimum of two plant introductions will be put into the trade each year. The plants released are either processed through the Canadian Ornamental Plant Foundation (COPF) for royalty purposes or, if it is a selected clone or recommended plant, the royalties are then returned to the Botanical Garden directly.

The new introductions carry a distinctive P.I.S.B.G. label. An agreement is made with all propagators that any plants released must carry the P.I.S.B.G. label at the date of release. The Botanical Garden is responsible for the development of appropriate promotional material. This includes a one-page-flyer with a colored picture of the plant on one side with the basic information about the plant and, on the reverse side, written documentation outlining propagation, care and maintenance procedures, and possible areas of utilization for the new introduction.

Support of the Program. The program is supported by operational funds from the Botanical Garden obtained from the University of British Columbia. In addition, grant support has been made available through the Science Council of British Columbia and The Devonian Group of Charitable Foundations of Calgary, Alberta.

Future Considerations. The success of the program will not be known for several years but initial reaction from the industry has been positive. There is an obvious need for well-documented and carefully selected material to be introduced into the trade. The public clearly is receptive to new material and it provides an opportunity for the Botanical Garden to utilize its extensive collections in a positive way to create a greater diversity of horticultural material for public use.

Gardens are often accused of having a collection of collector's items and, in many senses, this is true. The P.I.S.B.G. program provides for a review of the collections to select those which are commercially viable and enhance the reputation

and role of the Botanical Garden as a public institution. The P.I.S.B.G. program also provides for a sound business-like arrangement between a public garden and the industry with both parties benefiting from financial gain through the introduction of new plant material.

The first two introductions in the program were released in August, 1983, and consist of *Genista pilosa* 'Vancouver Gold', a new registered cultivar, and *Microbiota decussata*, registered UBC clone 12701. They are ground covers that may be used extensively in both private and public programs. The two introductions will be released to the public on March 1, 1985. We anticipate up to four new introductions for the summer of 1984. We believe the P.I.S.B.G. will fulfill its objective of "a research program to enhance our landscaped environment" with the introduction of new plants over the next several years.

PROPAGATION BY DIRECT STICKING OF CUTTINGS IN A NUTRIENT MEDIUM

REGGIE HUNTER

Whisky Hill Nursery
7194 S. Barnards Road
Canby, Oregon 97013

We have been using the direct sticking method for rooting broadleaf cuttings for the last 3 years. The average success rate has been 90%. We have not been able to use this method for hardwood cuttings due to space problems. With direct sticking a cost savings is realized by eliminating the transplanting of the rooted cutting to a liner pot.

The medium, for one cu yd of mix, consists of ⅓ each of peat moss, pumice, and sawdust. To this is added 6 lb of Osmocote 18-6-12 and 1 lb of Micromax (do not use Micromax Plus). In order to keep the Osmocote inactive, we do not add water to the medium at this time. We use cell packs in 17 in. square flats rather than loose pots. The reason — time and space. The cell packs used are either 90 or 64 cells per flat. This same flat would hold only 49 2¼ in. pots. We purchase the cell pack sheets without perforations so that they do not fall apart with only one use. Two cell sizes are used to accommodate the material to be rooted. The smaller cell is used for almost everything except magnolias. The same medium is used in regular propagating flats when only rooted cuttings are needed for special orders. This gives us the same high quality root development as the cell packs.

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Cuttings are taken early in the morning to prevent wilting. They are soaked in a mixture of Diazanon and Kelthane at a rate of 2 tbs of each in 25 gal water. Cuttings are made and a rooting hormone is used in the usual manner. The flats of medium are watered lightly before the cuttings are placed into them. Flats are placed under mist immediately after sticking. The bed temperature is kept between 70° and 80°F. The greenhouse is kept between 85° and 90°F. Initially, the mist is held at a heavy rate, running this way for approximately one week so the foliage never drys. Mist is then decreased slowly as roots develop and plant growth begins. Mist is discontinued after 2 to 3 weeks when no wilting occurs.

Most material will be held over through the winter for transplanting the following spring. Potentilla that has been started in May may be transplanted by August or September. Magnolias are transplanted into 4-in pots by fall to allow for root growth. Cell packs that are held over are thoroughly drenched every 2 to 3 weeks to prevent disease, using Captan and Benlate, or Benlate and Truban. The rate is 4 oz of each to 100 gal water.

Liners are sheared often in order to have a well-branched plant. They then require less attention after transplanting. Most all of our summer cuttings have rooted and grown well in the medium described. We have experienced problems with only mock orange and heathers.

PROGRESS AND NEW IDEAS IN TISSUE CULTURE PROPAGATION

RANDALL W. BURR

B & B Laboratories, Inc.
1600D Dunbar Road
Mount Vernon, Washington 98273

There have been no recent discoveries of new substances which affect plant material and it is now a matter of adjusting formulas of the known ones to suit the needs of different plants and of refining our techniques for handling. This paper will chiefly consider the physical aspects of a tissue culture laboratory, with a brief overview of media and plant material handling. B & B Laboratories, like most plant enterprises, is interested in producing plant material in the most efficient way. The actual physical lab and the handling processes can be very costly and I will discuss ways in which costs have been held down at our lab. We grow a wide variety of plant

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material, ranging from woody shrubs (rhododendrons, azalea, kalmia, etc.) to ornamental trees, perennials, foliage plants, and bulbs.

Lab Construction and Operation. Our physical building is of a modular construction and built within a large open warehouse of 3,500 sq ft. The present lab size is 1,400 sq ft but is now being expanded. The walls are of 4×8 ft panelled sections and the ceiling is made of 4×12 ft sections. Because these sections are bolted together rooms can be added or changed in size or configuration easily to accommodate changing needs.

To keep the air cleaned and the temperature controlled, we use an air filtration system which recycles warmed air in winter or brings in cooler outside air in summer. This can be tied to a heat pump system to add heating or cooling as necessary. The use of outside or recycled air greatly reduces the cost of operating the heat pump or air conditioning unit. (This has also been done with good results at the Briggs Nursery tissue culture lab in Olympia, Washington.) The air is filtered before entering the lab with a hepa type filter. We have a separate air system for each room so that we can maintain different temperatures in separate areas as our plant and employee needs require.

The media preparation area is U-shaped to facilitate an even work flow, starting on the right side with a household refrigerator and counter top, with shelves above which hold all chemicals, stock solutions, and the scales. In the center is the sink with the distilled water unit and the dishwasher. The left side has the pH meter, counter-top stove, and the stirrer for cooking, followed by counter space for filling the tubes and containers, then the autoclave and cooling shelves which connect to the cutting area.

In the cutting area we use simple air filtration stations based on a design from Dr. Wilbur Anderson of the Northwest Washington Research Station, Mount Vernon, Washington. The stations use only one ½ in thick filter-down filter because the air going into the room has already been cleaned. We have been using the stations for more than 4 years and they have proven adequate and are much cheaper to build and maintain than the commercially produced laminar air stations. All air entering the rooms passes through a 12 in. hepa filter.

We find it advantageous to use several culture rooms rather than one large one. This way we can create different temperatures and lighting (intensity and photoperiods) for different kinds of plants; for example, we use a dark warm room for lily bulbs, a lighted and warm room for foliage plants, and a lighted and cool room for trees, shrubs, and perennials.

Sometimes, in order to avoid unnecessary handling, we store plant material for use at a later date. For example, we store lily bulbs, rhododendrons, and perennials by sealing the culture tubes with Celons (to eliminate contamination) and keep them for up to six months at 34°F in an unlit 38 cu ft refrigerator which was made for the food industry and which we bought used at a fraction of the cost of a new one.

Containers, Space and Handling. We still grow mostly in 25 mm culture tubes because we started with them and have them on hand. They are placed on slant trays we made ourselves. In the future we will stand the tubes upright as we can afford the changeover. This alone could double the capacity of the culture rooms, delaying the need for more rooms. We are considering the two types of Majenta trays for this. One holds 30 tubes and the other 36. The latter would require use of clear caps for the tubes, while with the 30-tube holder, we could still use our opaque caps.

We have also begun to use the Magenta GA-7 container for plant material which grows fairly large and we are considering baby food jars with the Magenta lid as a possible growing container which would also save space in the culture rooms.

We identify our containers and tubes with stamps giving date, cultivar, and cutter initials on round or oblong labels meant for office use. They are easily put on and removed.

Bill Brown of B & B Laboratories has designed and built a media-dispensing machine which fills 40 tubes at a time and can fill 480 tubes in 3 to 4 minutes. The concept and design has been turned over to Bellco, Inc. in New Jersey for development and marketing. It has been a valuable time saver for us because we use so many tubes. He will doubtless also design a similar machine for dispensing into baby food jars and the GA-7s.

We find that by reducing the agar amount slightly we are able to avoid emptying the tubes of the medium before running them through our household dishwasher, which holds 200 tubes in five racks and cycles in 30 minutes. There are commercial dishwashers which cycle in 2 minutes and do a little better job. They use more electricity but make up for that cost in efficiency.

Media. We use three basic salt formulations: Murashige-Skoog at various concentrations, Anderson's rhododendron, and Lepoivre; we keep stock solutions of these on hand at all times.

We use the inexpensive gum agar from Sigma Chemical, St. Louis, Missouri, and have had no problems with the plants. Different agars and gelling agents work differently and I feel

that it is important to use one exclusively in order to get consistent results.

As with all other aspects of our operation, we try to keep media preparation as simple as possible and often eliminate the many kinds of media addenda which appear in the published papers without apparent harm to plant performance. We do use i-inositol, thiamine HCl, and adenine sulfate-H_2O where appropriate.

Shipping. We ship nearly all of our products *in vitro* in a rooting medium using two types of containers, both of which are made for the food industry where mass production brings the unit price down. One type is a clear plastic food tray 4½×4½× 2 in. with a heat-sealed Mylar covering which makes it air-tight. These are sterilized by soaking in a 10% household bleach solution for 10 minutes. The second type is a slightly larger aluminum tray with a clear plastic lid which is crimped on. We sterilize the trays in the autoclave in a turkey roasting plastic bag along with the medium to be dispensed and the lids are soaked in the bleach solution. We sterilize the rooting media in the autoclave in quart jars and dispense into the trays in a special pouring hood built at the lab. We make 6 liters at a time which fills 60 trays.

Both trays are lightweight and disposable and therefore good for shipping. The plastic trays cost about $0.06 each and the aluminum ones cost more than twice as much. The reason we use the more expensive one is that some plants need the breathability of its less-tight closure. We are experimenting with various ways to ventilate the plastic trays to alleviate any gas build-up problems.

We ship 72 to 75 trays per 22×14×12 in. box in which 1800 to 3750 plants, depending on the species. The box can be packed in 10 minutes or less. If we were to remove the plants from their trays and put them in plastic bags, we could ship tens of thousands per box, but that would require several hours of labor, increasing our cost, and the grower would have to handle the plants immediately upon their arrival.

In conclusion, we feel that in order to have an efficient plant propagation unit we need to look around, sometimes outside the industry, for ideas to use for the production, handling, and delivery of tissue-cultured plant material and not be afraid to try something different. We need to improvise, experiment, and keep asking these questions: Why are we doing it this way? Could it be done faster or easier? Is it cost effective?

THE IMPORTANCE OF TIMING IN PROPAGATION BY CUTTINGS

EDWARD W. SCHULTZ

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There seem to be more contradictions in scientific experimentation in the plant propagation field than in any other phase of horticulture.

Ask any propagator the proper time to take cuttings of a given species. He will say, "take your cuttings in November, April, or July and you can expect 100% rooting."

My personal experiences keep me from making any calendar predictions on timing. Weather patterns change from year to year. Erratic results arise from various cultural practices. Stock plants grown in a greenhouse, a shadehouse or outdoors, irrigated or non-irrigated, well-fertilized, or starved will lead to different responses.

Since each of these factors can change rooting from 0 to 100% and interact with the time taken, it is not a surprise to find some dogmatic conclusions that cannot be verified by repeated trials.

My first experience in timing in the taking of camellia cuttings occurred in 1951. The nursery owner would check the maturity of the wood by using the snap method. In early July the new shoots would be bent back. If the stem collapsed it was not mature enough. If it would snap we would make cuttings of that particular cultivar. Years later I realized that the same shoots might snap on a cool, damp morning but not on a hot, sunny afternoon.

Sometimes if the stem tip is soft and too succulent it can be removed and the lower portion will have the proper maturity.

A number of years ago the Rhododendron Society held a meeting in Portland discussing timing in making rhododendron cuttings. Each speaker had a favorite time for taking cuttings which varied from June to November. All seemed to agree on taking the more mature cuttings first except one grower at the coast. He said "I take my cuttings very scientifically. I start with the letter A and put in 'Anne Bedford', 'Augfast', etc., then go on to the letter B."

One grower told me to take ivy cuttings on March 1 for best results, but I have taken them every month of the year and I get nearly 100% rooting.

Since a cutting roots from the energy it has stored, the maturity of the cutting should be and is a major factor in timing.

The question arises in rooting cuttings, are there any plants that have a calendar or seasonal optimum time. At our nursery we root junipers and arborvitaes from December 1 to about April 1, or when spring growth begins. Even then I prefer to wait until after a hard freeze and the plant has had its cold requirements satisfied so that it will grow normally in the spring.

On the other hand, the timing for rooting cuttings in the genus *Chamaecyparis* does not appear to be as exacting in our area.

Broadleaved evergreens and deciduous plants and trees are usually propagated by cuttings in late spring and summer after the first flush of new growth begins to mature. Magnolias, smokebush, and barberries are also successfully rooted at this time.

About the time I become positive as to the exact time to take cuttings someone shows me 100% rooting of a species taken at what I consider the "wrong" time. I then move back to square one and become less positive than ever that timing by the calendar is of any benefit at all.

BRUCE BRIGGS: Ellen, have you tried putting your *Liquidambar* explants into a liquid as well as a solid medium?

ELLEN SUTTER: No, we have not. We have had problems at times with internal contamination so we have used shorter and shorter buds. With short buds, as a chip bud, we cannot put them in liquid medium so we stay with the agar.

BARRIE COATE: Wouldn't it be advisable for propagators in the Pacific Northwest to be looking for specific *Liquidambar* clones which do well in this climate? There is a need for *Liquidambar* clones superior to those now available. On another subject — an interesting rejuvenation procedure has been used with a number of species which has increased rooting percentages considerably, for example with *Ceanothus* 'Julia Phelps,' a silver form of *Sequoia sempervirens*, and with *Quercus ilex*. In the latter case we cut down a 20 ft. stock plant in the field, which stump sprouted. The sprouts then rooted easily, being due probably to this rejuvenation procedure. This can be applied to many more species, I believe.

WARREN ROBERTS: This question is for Larry Landauer. Can you name any rhododendron cultivar that can be grown under alkali conditions, such as we have in the central valley of California?

LARRY LANDAUER: There are rhododendrons that will grow under alkali conditions, not well — but they will grow. However, when you combine alkaline soil with high temperatures, rhododendrons will not make it. They can tolerate one or the other of these conditions, but not both together.

ED SCHULTZ: How early in the season do you start taking rhododendron cuttings?

LARRY LANDAUER: We start June first, starting with the dwarf types — on through the end of December. You can root a rhododendron cutting anytime of the year the wood is hard enough to stick into the rooting medium. We have rooted 12 months of the year.

MICROPROPAGATION OF FILBERTS, *CORYLUS AVELLANA*[1,2]

WILBUR C. ANDERSON

Washington State University

Northwestern Washington Research Unit

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Abstract. A micropropagation system is described for shoot multiplication and root initiation followed by a successful transfer of filbert plantlets to soil in a greenhouse environment. Essential factors beneficial for shoot multiplication were the combination of two cytokinins, BAP and 2iP, and the incorporation of Anderson's inorganics, a low salt medium. Shoot proliferation arose primarily from lateral bud break. Proliferated shoots were subcultured on shoot elongation/rooting medium, then planted into greenhouse soil and placed into a humidity tent. The survival of the micropropagated filberts was 93%.

INTRODUCTION

The primary objectives of this research was to develop commercially feasible micropropagation techniques for filberts. Micropropagation of filberts may be an attractive alternative propagation method because of reductions in both costs of production and time required to introduce commercial quantities of new cultivars to the industry.

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[1] Scientific Paper No. 6735, College of Agriculture, Research Center, Washington State University, Pullman, Washington 99164.

[2] Author gratefully acknowledges partial financial support provided by the Oregon Filbert Commission for this research project.

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In order to have a commercially feasible micropropagation system for filberts, three major objectives must be met: there should be an economic yield of useable propagules per subculture; the propagules should be successfully transferred to greenhouse conditions with minimial loss; and the system must maintain the genetic integrity of the cultivar or breeding line propagated. This paper address the first two objectives: adequate rates of shoot multiplication and successful establishment of the micropropagated plantlets in the greenhouse environment.

METHODS AND MATERIALS

Seedling Source of Explants. Recently harvested nuts were cracked and kernels placed on a tray. Kernels were then incubated 4 hrs in a 50 mg per liter (GA-3) solution one cm deep at 20°C. The kernels were planted in plastic flats and sprouted in the greenhouse. Softwood shoots were excised from the seedlings after they were 10 to 15 cm high, surface disinfested for 15 to 20 minutes with diluted bleach (0.53% sodium hypochlorite), containing 1 ml per liter Tween 20. Disinfestation was stopped by rinsing with sterile water. Lateral buds with about 0.5 cm stem section were excised and planted on semi-solid culture medium.

Source of Explants of cv. Daviana. Trees were grown in the greenhouse and the shoots were allowed to complete the first flush of growth. Softwood shoots were then removed from the trees, surface disinfested, and explanted like seedling explants. Contamination rates for tree explants, however, were over 90% indicating an alternative explanting technique must be developed for micropropagation of cultivars.

Basic Culture Medium and Environment. The initial culture medium was that of Anderson, (1,2) which is a modification of the Murashige and Skoog (5) formula with approximately 75% reduction in the concentration of ammonium nitrate and potassium nitrate and with other modifications of the medium involving phosphate, iron, and iodine. The organic constituents and concentrations (Table 5) were primarily those of Linsmaier and Skoog (e.g. inositol and thiamine). Sucrose and adenine sulfate concentrations followed the guidelines of Murashige (6).

The basal medium contained (per liter): sucrose (30 g), i-inositol (100 mg), adenine sulphate dihydrate (80 mg), thiamine HCl (0.4 mg), IAA (1 mg), kinetin (1 mg), and Phytagar (6 g). The pH was adjusted to 5.7 $\pm$ 0.1 with NaOH and HCl. The medium was dispensed 20 ml per 25 $\times$ 150 mm culture tube and autoclaved at 125°C and 1.05 kg/cm^2 pressure for 15 min-

utes. The standard culture conditions were 1,000 lux light, cool white fluorescent, 16 hr per day, and a constant 20°C. Standard length of time between subcultures was one month.

Description of Experimental Plant Materials and Treatment Design Used in These Experiments. Shoot tips (7 to 10 mm long), and generally with 3 to 4 expanded leaves, were harvested from existing multiplying cultures. These shoots, which were the initial propagules for most experiments, were placed upright with the basal cut portion pushed down into the semi-solid medium. A minimum of 10 replicate cultures were utilized for each treatment. Standard error of the mean was calculated to document variation within each treatment. (7).

RESULTS AND DISCUSSION

Experiments defining culture conditions were done with seedling source plant material; the cultures of the cultivar, Daviana, have been established and successfully propagated utilizing the system developed through the research presented here.

Initial Cytokinin Auxin Test. Cytokinins tested were kinetin, 6-benzylaminopurine (BAP), and N_6-(2-isopentenyl)-adenine (2iP) at 1.0, 2.5, and 5.0 mg per liter. Kinetin was ineffective in causing shoot multiplication. BAP at all concentrations produced healthy shoots but only caused some shoot multiplication for the highest concentration. The most effective 2iP treatment for shoot multiplication was 5.0 mg per liter.

Auxins tested were indole-3-acetic acid (IAA), indole-3-butyric acid (IBA), and β-naphthaleneacetic acid (NAA), at 1.0, 2.5, and 5.0 mg per liter with 1 mg per liter 2iP being the basal cytokinin. NAA caused callus to form on the basal portion of the shoot that was in contact with the media. IBA and IAA were both about equal for root initiation except IBA had greater phytotoxic effects at 2.5 and 5.0 mg liter. Combining IAA and 2iP in a single treatment resulted in leaf and stem necrosis.

Combination of Cytokinins, BAP and 2iP. Combinations of BAP and 2iP were tested when it was observed that cultures coming directly from a medium of BAP and then cultured on 2iP had very good shoot multiplication. The first experiment indicated that combinations of 1 mg per liter 2iP and 4 mg per liter BAP were best for shoot multiplication. Subsequent reculturing on that medium, however, was phytotoxic. Further factorial testing showed that combinations of 2 mg per liter BAP and 1 mg per liter 2iP were optimal (Table 1). Addition of IAA at 1 mg per liter had no beneficial effect in any of the cyto-

kinin combination treatments (Table 1). The growth regulator concentration rates finally adopted after numerous recultures and experiments was 1 mg per liter 2iP, 2 mg per liter BAP, and no auxin. Shoot multiplication utilizing this hormone combination causes lateral bud breaking followed by vigorous shoot growth.

Table 1. Effect of BAP and 2iP concentrations on numbers of shoots proliferated in a one month incubation period starting from shoot tips.[1]

BAP mg/l	0 mg/liter IAA			1 mg/liter IAA		
	2iP (mg/liter)			2iP (mg/liter)		
	0	1	2	0	1	2
0	1.0±0	1.0±0	1.3±0.2	1.0±0	1.0±0	1.0±0
1	1.2±0.2	1.4±0.2	1.2±0.2	1.1±0.1	1.1±0.1	1.1±0.1
2	1.3±0.2	2.2±0.7	2.2±0.7	1.3±0.2	1.2±0.2	1.4±0.2
3	1.8±0.6	2.1±0.6	2.1±0.6	1.6±0.2	1.5±0.2	1.5±0.2

[1] The basal medium contained either no or 1 mg per liter IAA.

Inorganic Formulas and Shoot Multiplication. The three inorganic formulas compared (Table 2) were Murashige & Skoog (MS)(6), Lloyd & McCown (LM) and Anderson (A)(1). Shoot multiplication rates were followed for three consecutive subcultures. Shoots produced in the MS medium had foliage that was pale yellow similar to that expected from salinity toxicity. The shoots in the LM medium showed greater variability. The number of shoots produced in the subcultures of the LM medium was approximately 75% of those grown on the MS formula. The A medium, however, was the most consistent and had the greatest shoot multiplication, producing 150% of the shoots of the MS medium.

Table 2. Comparison of inorganic formulas on the number of shoots proliferated per incubation in three consecutive subcultures[1].

Inorganic Formula	Subcultures		
	1	2	3
Anderson	4.5±0.6	5.4±1.0	14.2±2.4
Murashige & Skoog	2.0±0.2	3.5±0.7	10.7±2.9
Lloyd & McCown	2.3±0.3	2.7±0.6	7.3±2.2

[1] The first subculture was initiated with shoot tips while the second and third cultures were derived from shoot bases and recultured on the same inorganic treatment.

Comparison Between Shoot Tips and Shoot Bases for Shoot Multiplication. The growth of shoot tips was characterized by greater internodal space ranging up to 3 to 6 mm. In contrast, recultured shoot bases had many compressed nodes. Comparing shoots produced from shoot bases resulted in sig-

nificantly greater shoot proliferation rates than shoot tips, especially during the second and third recultures (Table 3).

Table 3. Number of shoots proliferated per subculture from shoot tips and basal stems in three consecutive subcultures.

Subculture	Shoot Tips	Basal Portions of stem
1	3.0±0.3	4.5±0.3
2	1.9±0.2	6.4±1.1
3	2.5±0.2	14.6±0.8

Shoot Elongation and Rooting. Preliminary experiments with auxins indicated IAA and IBA were effective in root initiation. The data from one test utilized 0.5× strength Anderson inorganics and organics at the following rates per liter, sucrose (30 g), inositol (100 mg), thiamine HCl (0.4 mg), IBA (0.5 mg), and Phytagar (6 g). After 5 weeks incubation, 65% of the cuttings rooted and all shoots elongated at least 1 cm.

Greenhouse Care. The micropropagated plantlets were planted in 1:1 mixture of Redi-earth and horticultural perlite. A fungicide mixture of 150 mg Benlate and 150 mg Captan per liter was sprayed after planting and at three to five day intervals. The plantlets were placed under a humidity tent for three weeks during which time all started new shoot growth. Survival of 250 plantlets after one month was 93 percent.

The media we used for filbert micropropagation are summarized in Table 4 and include the appropriate plant growth regulators and their concentrations and the most effective inorganic formula tested for both shoot multiplication and rooting. Shoot multiplication is primarily from lateral bud breaking. Consequently, the best multiplying propagules are from the basal portions of recultured stems. (Figure 1).

Table 4. Composition of filbert media for shoot multiplication and shoot elongation/rooting.

	Shoot multiplication (amount per liter)	Shoot elongation and rooting (amount per liter)
Sucrose	30 g	30 g
Inorganics	Anderson	Anderson 0.5×
Organics		
i-inositol	100 mg	100 mg
adenine sulfate dihydrate	80 mg	----
thiamine HCl	0.4 mg	0.4 mg
Growth Regulators		
IAA	----	0.5 mg
2iP	1-2 mg	----
BAP	2 mg	----
pH Adjusted		
with NaOH or HCl	5.7±0.1	5.7±0.1
Phytagar	6 mg	6 mg

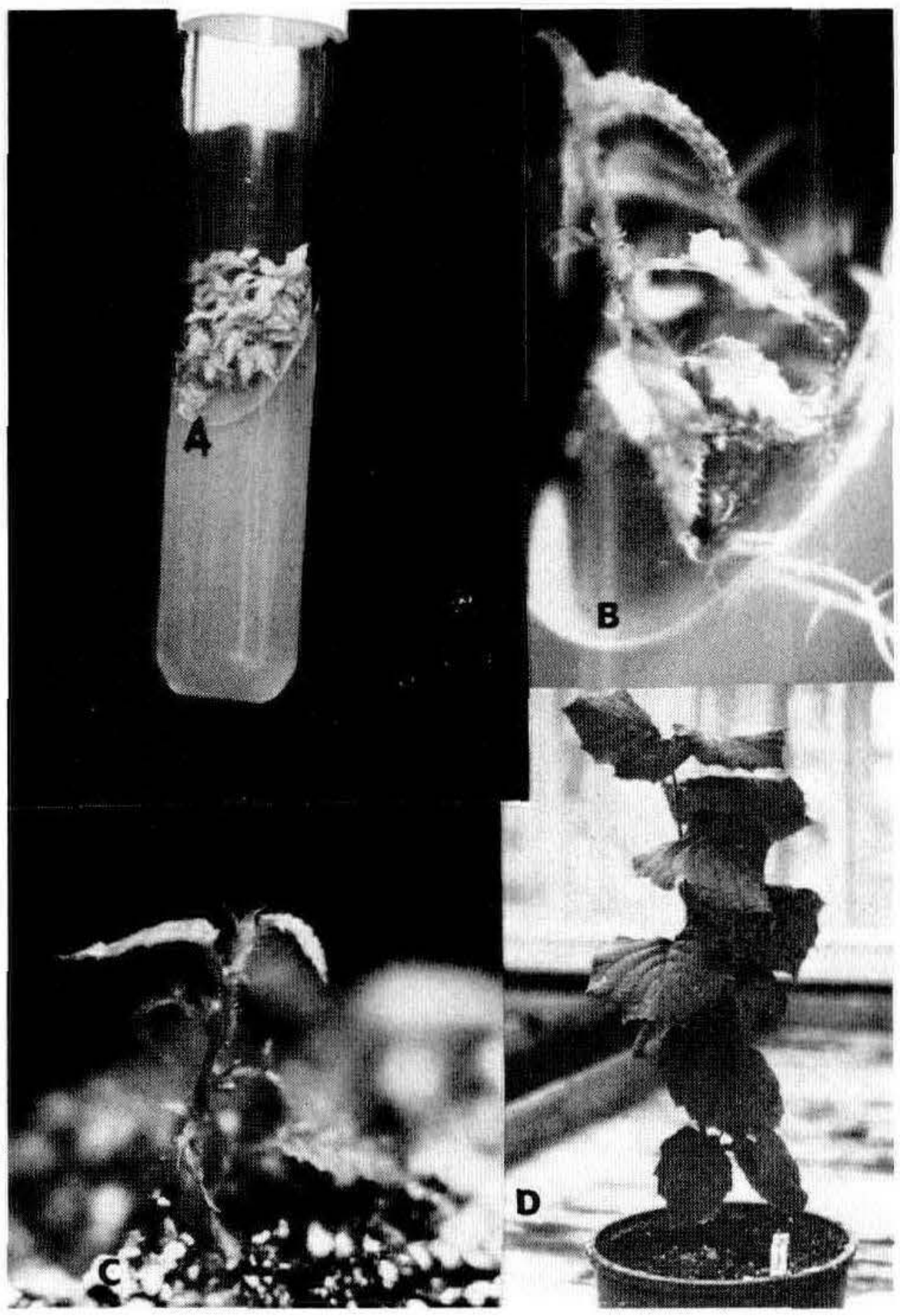

Figure 1. A. (upper left). Shoot multiplication culture arising from a subcultured basal portion of a shoot; B. (upper right). Plantlet derived from the shoot elongation/rooting medium five weeks after subculturing; C. (lower left). Plantlet three weeks after planting in soil and acclimatization in humidity tent; D. (lower right). Filbert tree three months after tissue culturing.

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EXOTIC TROPICAL AND SUB-TROPICAL FRUITS AND NUTS AND THE AUSTRALIAN PLANT PROPAGATOR

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Relative importance of the tropical and sub-tropical fruit industries in Australia. Apart from the banana (*Musa* spp.) and the pineapple (*Ananas comosus*), there are few tropical or sub-tropical species that could be considered major horticultural crops in Australia. Compared with those of the temperate areas of Australia they are very minor (Table 1). However, the area of exotic tree fruit production is rapidly expanding in a period when horticultural plantings are either static or contracting. Exotic tree fruits may never rival the grape or citrus industries in size, but they will have an increasingly important role in Australian horticulture. Perhaps more importantly, however, they will add considerable variety to our fruit diet.

Table 1. Fruit Statistics for Australia, 1981-82.

	Area in 1000 hectares	Production in 1000 tons	Value in $1000
Grapes	68.3	886	211.4
Citrus	27.5	477	113.6
Pome fruits	27.3	404	152.2
Stone fruits	22.1	118	78.4
Nuts	7.7	3.1	9.3
Banana	8.7	130	60.4
Pineapple	6.4	126	21.5
Macadamia	2.9	1.4	N.A.
Avocado	2.3	2.4	N.A.
Mango	1.1	2.3	N.A.

Source: Australian Bureau of Statistics, 1983

Fruits with potential for expansion. There is a group of fruits that are known to the Australian consumer, and for which there is considerable scope for further market development. Included in this category are the avocado (*Persea americana*), macadamia (*Macadamia integrifolia*), mango (*Mangifera indica*), litchi (*Litchi chinensis*), custard apple and relatives (*Annona* spp.) and cashew (*Anacardium occidentale*). Some of these fruits have a limited season of market availability which can be expanded by growing cultivars in areas of different times of maturity or by growing cultivars with different seasons of maturity in the same area. The times of fruit maturity (Figure 1) of the mango cultivars Sabre, Carrie, Kensington, Valencia Pride, Haden, Irwin and Zill for the locations Darwin

(Northern Territory), Bowen and Walkamin (Queensland) illustrate this point (9)

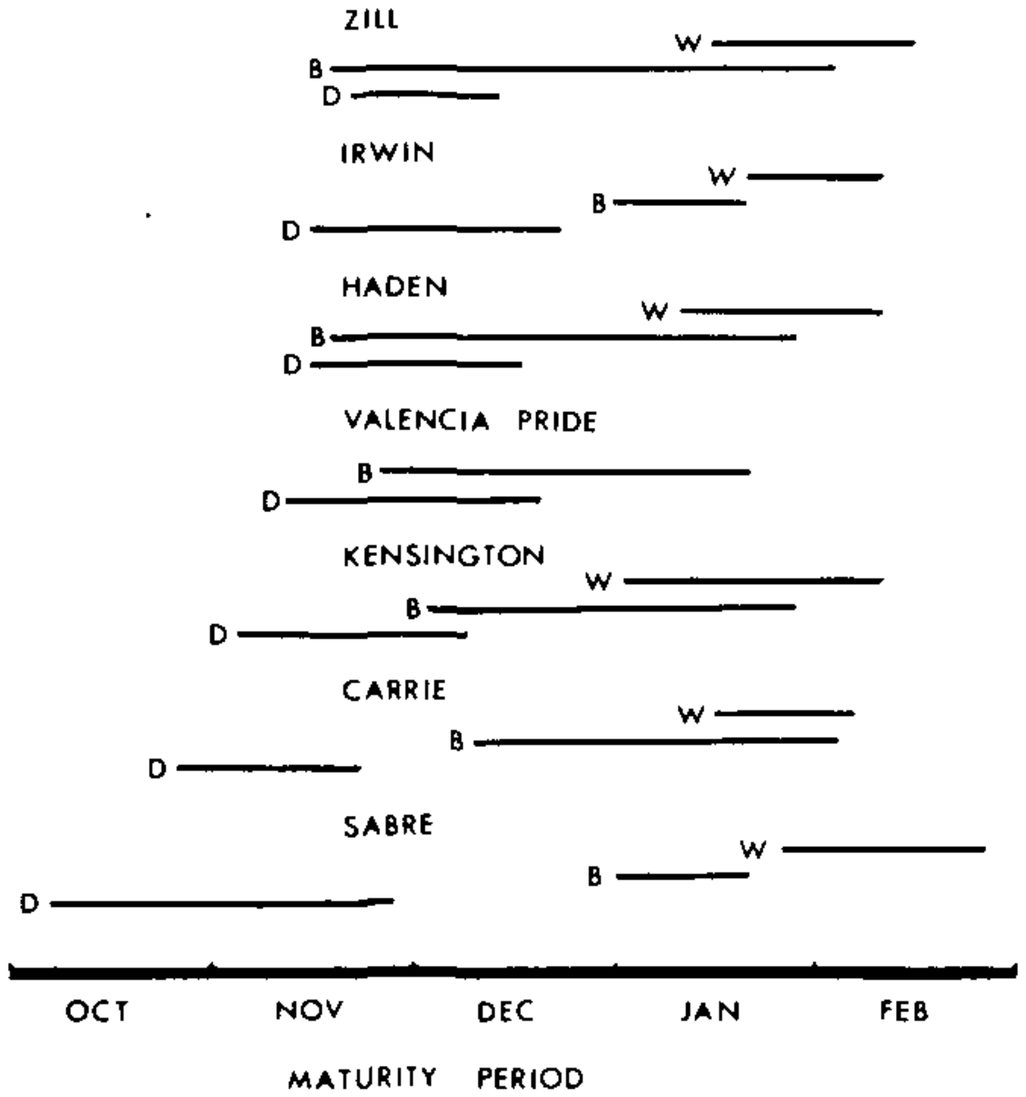

Figure 1. A comparison of the spring and summer maturity seasons for the mango cultivars Sabre, Carrie, Kensington, Valencia Pride, Haden, Irwin, and Zill grown at **Darwin (D), Bowen (B)** and **Walkamin (W).**

There is another group of exotic fruits that are virtually unknown in the Australian marketplace, but some of them have excellent potential for development for Australian and export markets. These are the rambutan *(Nephelium lappaceum),* mangosteen *(Garcinia mangostana),* sapodilla *(Manilkara zapota),* carambola *(Averrhoa carambola),* jackfruit *(Artocarpus heterophyllus),* durian *(Durio zibethinus)* and duku or langsat *(Lansium domesticum).*

Present status of these fruits. Many of the species mentioned above were introduced into tropical Australia when this area was first settled last century. The director of the Darwin Botanic Gardens, Maurice Holtze, introduced a large number of agricultural and horticultural species in his search for suitable crops for the Northern Territory (2). His report to the South Australian Government of 1887 stated that the mango, cashew, sapodilla, and other fruits were growing well and seemed suited to the environment. However for various reasons these fruits did not develop commercially. In the last 10 years there has been an increased awareness of the horticultural potential of some of these tropical fruits and a large number of superior cultivars have been imported from overseas by governmental authorities and private individuals.

These cultivars have been released, are being propagated in increasing numbers, and are slowly becoming commercially available.

Associated with these introduction programs are experimental assessments of the cultivars in several areas of tropical Australian. Recommendations for commercial planting will emerge from these trials, but often growers and propagators use their judgement and make calculated decisions before all performance data is collected.

Propagation peculiarities of some of these fruits species. Many tropical fruits have recalcitrant seeds with a very short storage life. The rambutan, jackfruit, and durian have a viability of only a few weeks if stored under ideal conditions and much less if not stored properly (8), as many who have collected seeds in Asia for importation to Australia have found.

Polyembryony is the condition where a seed contains several asexual embryos as well as a sexual embryo, but the sexual embryo is usually weak or suppressed (5). Mango cultivars of Indo-China origin are usually polyembryonic while those of Indian origin are usually monoembryonic. The major Australian cultivar 'Kensington', or 'Bowen Special' is polyembryonic and is usually planted as seedlings which come "true-to-type".

Other species produce apomictic seedlings without fertilization, e.g. the duku (3) and mangosteen (7).

Trees of male and female sex (dioecy) are another frustration of the horticulturist. Seedling rambutans may be female, male or hermaphrodite (10). Superior clonal selections are hermaphrodite. Some member of the *Euphorbiaceae* family also exhibit dioecy.

Vegetative Propagation. Vegetative propagation is essential to: maintain superior clones, hasten the time to fruiting, and reduce tree size and modify the growth habit of the tree.

Propagation practices used in other countries for these species range from the simplest form of harvesting fruits and nuts from native trees in the forests (Brazil nuts *(Bertholletia excelsa)* in South America and durian in Indonesia), to sophisticated techniques such as approach grafting, multiple grafting, and inarching practices that are used in some Asian countries, in addition to grafting and budding. However, these countries often have access to cheap labour, and although we can learn much from them, the propagation technology may not be directly transposed to Australia and may need some adaptation to suit our situation.

Tissue culture is often seen as the answer to all plant propagation problems. Successful tissue culture of woody perennial species is difficult, but a considerable number of researchers are working on this problem and future success is certain.

Propagation Problems of Tropical Fruits. A major problem in the propagation of tropical tree fruits is lack of information on rootstocks. Other, more developed horticultural species have rootstocks for disease resistance, salt exclusion, and size control but this information is lacking for most tropical tree fruits. Also, the disease status of rootstocks and scions (particularly viruses and viroids) is poorly understood. It is often assumed that there are no virus diseases of these species but they probably exist and have yet to be found. A clone of rambutan (R_3) which exhibited some dwarf characteristics has recently been shown to have a virus disease (A.R. Shaari, personal communication).

The avocado as an example. The avocado is probably the most understood of the tropical and sub-tropical tree fruits but this has only occurred in recent years.

Mother-plantings of rootstock source trees and scion-budwood source trees have been indexed for freedom from sunblotch disease and then registered as part of a viroid-tested tree registration programme (Australian Avocado Growers' Federation 1980). Nursery plants propagated using this disease-free material are identified for rootstock and scion source.

Clonal avocado rootstocks are commercially available from some California nurseries. Avocado cuttings are difficult to root, but a system of etiolation increases rooting success (6). The technique is lengthy and expensive but a double graft system using a "nurse-seedling" was developed which facilitated the production of clonal rootstocks in commercial quantities (4).

CONCLUSIONS

The tropical fruit and nut species described in this paper should develop as the avocado has done in recent years.

Specialised nurserymen must use the latest propagation technology to benefit the development of new horticultural industries in tropical areas.

Mother plantings of superior material (improved performance and disease-free) need to be established, and propagation systems, developed from overseas experience and adapted to Australian conditions, should produce quality plants which will form the foundation of the tropical fruit industry in Australia.

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INVESTIGATIONS OF GERMINATION AND BENCHING IN SWEET ORANGE SEED

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Abstract. In an attempt to improve seed germination and reduce benching in sweet orange and citrange seedlings, seeds were peeled, abraded, or treated with acid, gibberellin, or cellulytic enzymes. Peeled or acid-treated seeds germinated rapidly. Only peeled seeds grown with bottom-heat and mist-watering showed reduced benching. Thus the testa affects germination, but additional factors contribute to benching.

INTRODUCTION

There are two aspects of plant growth which cause concern in the commercial production of citrus seedlings. First, the amount and rate of seed germination and, second, the relative straightness of the stem.

Germination performance has many obvious and important effects on the management of the citrus nursery. Good seed quality (of high specific gravity and stored under favourable conditions) and freedom from disease are necessary prerequisites. Furthermore, germination and early seedling growth are sensitive to temperature and water conditions; the large effects of temperature and the value of bottom-heat were stressed by Kumar (5). Also, the value of minimal water stress is well demonstrated by the success of misting techniques. Despite the application of this knowledge, the germination of sweet orange *(Citrus sinensis)* seeds and those of *C. sinensis* × *Poncirus trifoliata* hybrids remains unreliable.

The second aspect, stem straightness, relates to the phenomenon called "benching" whereby a proportion of seedlings develop with bends, twists, and loops in the stem near the seed (3,6,7). These defects are not serious when the seedlings are grown in a field nursery for a year or more before budding since, at lifting, only looped seedlings have to be discarded. But when seedlings are to be budded at a young age, in a nursery system based on rapid turnover of container-grown plants, benching may lead to a large degree of culling at the first transplanting stage.

It is possible that variable germination and benching are both associated with the properties of the testas (seed coats) of

seed derived from *C. sinensis*. The effects of the testas could by physical (due to impeded gas or water exchange, or to mechanical interference with elongation of the radicle and stem) or chemical (in particular due to water-soluble growth inhibitors present in the testa). On the assumption that treatments which weaken the testa should lessen these problems, a variety of acid, abrasion, and enzyme treatments were tested in this study.

MATERIALS AND METHODS

Four randomised block experiments were carried out: two were commenced in water (Exp. 1 on July 20, Exp. 2 on August 20) and two in summer (Exps. 3 and 4 on December 11). The first two experiments were conducted at Renmark, South Australia using 'Troyer' citrange seed. After treatment the seed was planted uniformly in flats at 25 mm spacings using plots of 42 (Exp. 1) or 28 (Exp. 2) seeds. These were held in a polythene-sheet house under mist with bottom-heat.

Exps. 3 and 4 were performed at the Waite Agricultural Research Institute using sweet orange seed planted in pots, one plot of 36 seeds (25 mm spacing) per pot. These were held in a glasshouse with evaporative cooling, and watered daily. For all experiments three replicates were used. Both seed lots were 100% reactive to tetrazolium (8), indicating that the seeds were viable.

As controls, untreated seeds were planted dry (control-dry) or presoaked in water for 1 day (control-presoaked). In Experiments 1, 3 and 4 one treatment consisted of peeled seeds; the testas were removed by hand after soaking for 2 hours in water.

Acid digestion of the testa was tested preliminarily in Exp. 1 and extensively in Exps. 2 and 3. Seeds were immersed in 50% sulfuric acid for the times specified (¼ to 4 hours), then rinsed extensively in water before planting. In Experiment 1 a second acid treatment was used consisting of a 4 hour dip in 25% hydrochloric acid plus 0.25M zinc chloride.

Abrasion of the testa was tested extensively in Experiments 1, 2 and 3 using a variety of abrasion methods. In Exp. 1 the dry seed was tumbled at 50 rpm in a 2 l. lidded glass jar lined with carborundum paper on horizontal rollers for 12 hours. In Exp. 2 a tougher paper was used (cc-280-cw silicon carbide wet-and-dry sandpaper) lining a closed cylindrical tin and run for longer times (48, 72 and 96 hours). In Exp. 3 wet seed was tumbled for varying periods to achieve a specified percentage of abraded testas, sufficient to reveal the cotyle-

dons; in the most severe treatment seeds were rotated to the 90% abrasion stage, then for an additional 12 hours. Dry seed abraded to 50% was also included.

As used by Burns and Coggins (2), gibberellin was applied by soaking the seed in aqueous GA_3, 1000 ppm in Exp. 1 and 100 ppm in Exp. 2. This treatment was combined factorially with other treatments in Exp. 2. After the acid or abrasion treatments the seed lots were halved and soaked in either water or GA_3 solution.

Enzymatic digestion was attempted in Exps. 1 and 4, using cellulase (Onozuka R-10) and pectinase (ex *Aspergillus niger)* both at 2% w/v in 50 mm citrate buffer pH 4.5 at 30°C. The digestion was continued for 24 hours (Exp. 1) or for a variety of times (Exp. 4).

At intervals after planting emerged seedlings were counted. After about 4 months the seedlings were uprooted and classified into six categories of severity of benching as illustrated in Figure 1; grades 1 to 3 are regarded as acceptable for propagation. The tabulated "per cent benching" is the sum of grades 4, 5 and 6 per 1000 seedlings assessed. Many seeds produced multiple seedlings and the majority of seedlings were nucellar; the incidence of benching appeared similar in nucellar and zygotic seedlings so no record was kept of the separate populations. The data was analysed by Anova, and where the Variance Ratio was significant at $p = 0.05$, an LSD was calculated.

RESULTS AND DISCUSSION

The results of the four experiments are presented in Tables 1 to 4 and Figure 2. Comparisons may be made between Exps. 1 and 2, and between 3 and 4, as similar conditions and seed were used in each pair. In all experiments, the control seeds, with or without presoaking, germinated slowly but eventually produced more than one seedling per seed planted; about half of these seedlings were benched and judged unacceptable for budding.

Peeling. Hand peeling of citrange seeds produced very rapid germination and a low percentage of benching, yielding a high number of acceptable seedlings (Table 1). The germination of peeled sweet orange seed was also rapid but there was no increase in the final number nor any reduction in the percentage benched (Tables 3 and 4). It is now apparent that each species will require a separate program and that this information can not be extrapolated across species.

Table 1. Effects of several treatments on the germination and development of Troyer citrange seed (Exp. 1).

Treatment	Number of seedlings emerged (per 100 seeds planted) on:			Number benched per 100 seedlings	Final number of acceptable seedlings (per 100 seeds planted)
	Day 25	Day 70	Day 120		
Control-dry	1	62	128	37	79
Control-presoaked	5	43	127	36	83
Peeled	160	160	160	11	143
H_2SO_4 4h	1	3	6	11	5
HCl + $ZnCl_2$ 4h	3	56	85	38	52
Abraded	8	74	129	35	84
GA_3 1000 ppm	8	69	126	36	81
Pectinase + cellulase	8	79	99	48	57
LDS p = 0.05 (excluding peeled)	n.s.	6.8	13.4	n.s.	10.5

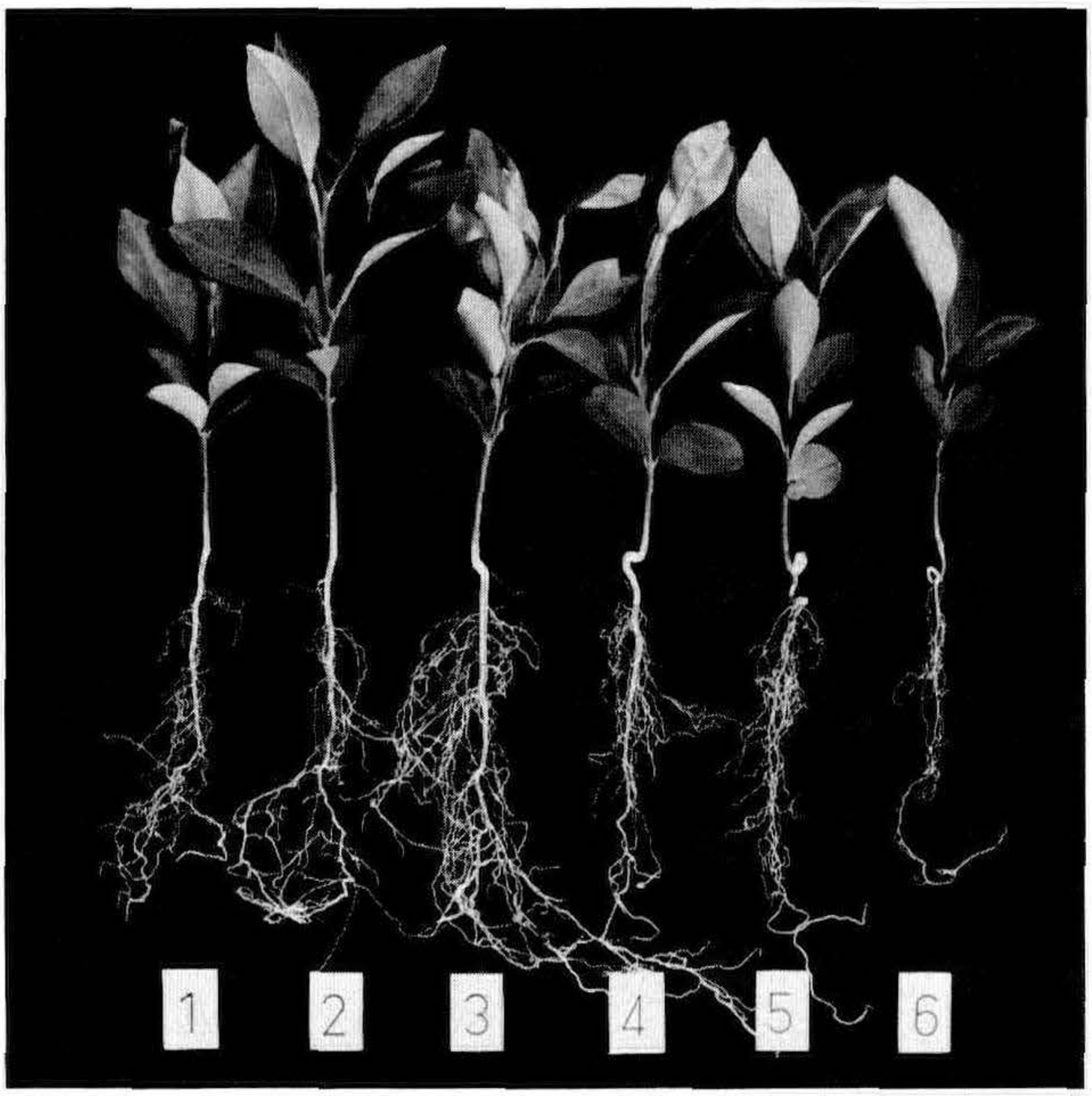

Figure 1. Sweet orange seedlings (Exps. 3 and 4) showing the six grades of severity of benching used for classification. Grades 1 to 3 are acceptable for propagation.

Acid Treatment. Clearly, 4 hours in 50% sulfuric acid (the treatment used routinely in our laboratory for dehusking barley) severely damaged citrus seed (Tables 1 and 2). Four hours in 25% hydrochloric with zinc chloride was less harmful.

Shortening the time of acid treatment caused less damage (Tables 2 and 3): one hour in 50% sulfuric acid resulted in significantly faster seed germination than in the control, though with no increase in the number of acceptable seedlings (Table 3 and Fig. 2); treatment for less than an hour had little effect.

Table 2. Effects of acid and scarification on germination and development of Troyer citrange seed (Exp.2)

Treatment		Number of seedlings emerged (per 100 seeds planted) on: Day 25	Day 120	Number benched per 100 seedlings	Final number of acceptable seedlings (per 100 seeds planted)
Control-presoaked		2	102	54	51
H_2SO_4	2h	15	32	37	20
	3h	5	19	37	12
	4h	1	2	*	*
H_2SO_4, then GA_3 100 ppm	2h	32	58	65	20
	3h	18	19	47	8
	4h	5	6	17	5
Abraded	48h	13	142	40	85
	72h	10	114	24	87
	96h	62	131	34	86
Abraded, then GA_3 100 ppm	48h	18	137	39	85
	72h	11	102	54	48
	96h	73	108	59	46
LSD p = 0.05		16.4	10.5	32.8	9.9

* 100% of the seedlings were benched but the population was small and therefore atypical

Abrasion. In some instances seed abrasion hastened seedling emergence. The dry abrasion used in Exp. 2 (Table 2) resulted in an increased number of acceptable seedlings. However, the treatments used in Exp. 3 (Table 3) caused no increase. Abrasion did not significantly affect benching.

Gibberellin. GA_3 at 1000 ppm had no effect by itself but, applied to abraded seed (Table 2), GA_3 at 100 ppm negated the improved emergence and acceptability deriving from abrasion. GA_3-treated seedlings were soft and spindly and some were chlorotic. The significant decline of benching recorded in the treatment with GA_3 + sulfuric acid for 4 hr (Table 2) is discounted because of the paucity of emerged seedlings.

Pectinase and Cellulase. A pectolytic enzyme has been used to recover seed from a seed-pulp mixture (1) so it was of interest to test the effect of enzymes under these conditions. Pectinase caused a marginal and temporary increase in the

rate of seed germination but enzymes had no other recorded effect (Table 4). In Exp. 1 the initial incubation softened the citrange seed testas but no modification of sweet orange seed was noted in Exps. 3 and 4. This highlights a general problem in exploiting enzymes: they may tolerate very little variation in conditions and material.

Table 3. Effects of acid and scarification on germination and development of sweet orange seed (Exp. 3).

Treatment		Number of seedlings emerged (per 100 seeds planted) on: Day 34	Day 51	Day 110	Number benched per 100 seedlings	Final number of acceptable seedlings (per 100 seeds planted)
Control-dry		5	46	152	77	34
Control-presoaked		4	46	153	66	52
Peeled		76	91	138	77	33
H_2SO_4	0.25 h	8	58	153	66	53
	0.50 h	7	68	145	67	45
	1.00 h	19	75	147	61	57
	2.00 h	7	63	117	73	31
Wet abrasion	5%	4	48	151	61	58
	50%	7	67	115	67	35
	90%	13	66	122	69	38
	>90%	14	43	69	56	30
Dry abrasion	50%	32	68	139	65	49
LSD p = 0.05		2.7	4.3	9.4	n.s.	n.s.

Table 4. Effects of enzyme digestion on the germination and development of sweet orange seed (Exp. 4).

Treatment		Number of seedlings emerged (per 100 seeds planted) on: Day 34	Day 51	Day 110	Number benched per 100 seedlings	Final number of acceptable seedlings (per 100 seeds planted)
Control-presoaked		5	44	142	50	71
Peeled		85	94	151	60	60
Cellulase & Pectinase						
	18 h	2	44	143	49	73
	24 h	7	40	129	45	72
	30 h	2	40	144	58	59
	36 h	6	44	149	55	68
Pectinase	24 h	4	52	144	49	73
	36 h	1	54	137	45	75
Cellulase	24 h	1	44	140	45	77
	36 h	7	42	134	45	73
LSD p = 0.05		0.7	5.6	n.s.	n.s.	n.s.

Figure 2. Plots of sweet orange seedlings from Exps. 3 and 4. The faster development of treated seeds relative to the presoaked controls (Water, 24 h.) is apparent, especially that from peeled seeds.

CONCLUSIONS

The treatment given had a variety of effects on seed germination and seedling growth of sweet orange and citrange, some detrimental and some helpful. Abrasion of the testa and treatment with enzymes or gibberellin gave variable results and did not increase the number of acceptable seedlings. Treatment with sulfuric acid gave a significantly faster germination though only when applied for a period of intermediate length; 1 hr was better than shorter or longer times.

At its best, acid treatment did not approach the high germination rate found with peeled seed. The beneficial effect of peeling was accompanied by a lowered percentage of benching in the case of Exp. 1 with Troyer citrange seed germinated with bottom-heat and under mist. Peeling caused no reduction in the percentage of benching in Exps. 3 and 4 despite its large significant effects in hastening germination.

It would appear, therefore, that benching is associated with more than the testa effect. Despite the lessened benching found in Exp. 1, compared with Exps. 3 and 4, it is not possible to say whether the lack of benching was associated with one or more of the following factors: seed type (sweet orange versus citrange), bottom-heat, misting, or the more rapid growth rate obtained in this experiment.

It is possible that initial growth rate is an important determinant of the likelihood of benching. Correction of a bend in the stem near the seed, caused initially by the chance a-position of that seed, is a geotropic response. Firn and Digby (4) consider that the tissues which perceive a geotropic signal are the outer layers of the stem and, further, that these are the tissues which effect the response. In any case the amount of the response varies with the growth rate of these tissues. It might be profitable therefore to compare early growth of sweet orange seedlings under temperature and water conditions that would influence stem growth rate.

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PROPAGATION OF *CORDYLINE TERMINALIS* 'SHEPPERDII' BY HYDROCULTURE

VIC FINES

Christmas Bush Nursery
Nelson Bay, New South Wales 2315

I had difficulty propagating *Cordyline terminals* 'Shepperdii' in quantity by the usual practice and searched for and developed the following method which yields almost 100% result. The method is also suitable for 'Tricolor Rosea', 'Red Edge', 'Baby-Ti', and other forms.

We propagate from plants at least 12 months old, preferably grown in very deep pots or well managed soil so as to allow maximum development of the rhizome. An application of Nemacur is given as protection against nematodes at planting.

The plants are removed from their garden beds or containers and washed free of all soil. They are placed on a wooden block and with a sharp knife 90% of the rhizome is cut off.

The leafy portion of the plants, with a small portion of the rhizomes and a few roots left on, are deeply planted in a suitable soil mix and watered in with a 1.5 ml/litre of Previcur and water solution. Then they are kept in humid conditions for 3 weeks and set out under shade cloth.

The remaining 90% portions of the rhizomes are cut into small sections, each having an eye and, if possible, a piece of root attached and dipped in a Captan solution.

As a propagating medium we use volcanic scoria or expanded clay. Other materials, such as perlite, vermiculite, charcoal, and river gravel have been used with some success but we much favor the scoria. The medium is put in a rectangular plastic container with 2 litres of water and sterilized in a commercial type microwave oven for 12 min at the high heat rate.

Propagating tubes (4 cm) are ¾ filled with scoria, a rhizome section with an eye is added and then covered with more scoria. These are placed in a plastic tray which is then filled to a depth of 2 cm with a solution of Previcur at the normal usage rate of 1.5 ml/litre. It is important that the liquid level be below the plant material.

We then place an opaque plastic tray of the same size on top to create a high humidity environment. When the water level goes below 1 cm it is brought up to the 2 cm level.

At 5 weeks we transfer the tubes to a fresh container and add a fresh Previcur-water solution. At 10 weeks the tubes are again transferred to a fresh tray and the Previcur solution is replaced by a ½ normal strength nutrient solution.

The plants that have emerged can be planted out or left to grow on in the nutrient solution until required. From the appearance of the first plant to the last a period of 3 to 7 months can elapse.

CONTROL OF FUSCHIA RUST

DEBORA H. LAW

Tamborine Mountain Plants
Long & Eagle Heights Roads
Eagle Heights, Queensland 4271

Abstract. In a comparative test a new product, Baycor®[1], significantly improved control of fuschia rust when compared with currently recommended Plantvax at single or double strength.

INTRODUCTION

Rust is a disease caused by fungi of the order of Uredinales in the Basidiomycetes characterized by a special type of reproductive structure. Being obligate parasites, rusts develop on living hosts. The pustules in which the rust spores develop provide that rusty look — hence the common term. The spores are easily spread by air movement and under suitable conditions rapidly penetrate a new host developing into new pustules in a week or so. In the case of fuchsias the rust is caused by a specific rust named *Uredo fuchsiae* Art. & Holw.

As with most groups of plant diseases, new strains of rusts may develop ability to resist available fungicides and so new strains of rust may appear on plants selected for their previous disease resistance.

In May, 1980 a rust infection of consequence was observed at the nursery and identified as *Uredo Fuchsiae*. The weather conditions at the time were excessively wet and warm, resulting in a significant commercial problem. There was a marked difference in cultivar susceptibility. For example, 'Pink Quartet' had quite severe infection and the newly introduced 'Bonanza' was extremely susceptible. 'Pixie', 'Lord Byron', 'Voodoo', and 'Party Frock' were infected but rust did not appreciatively affect appearance or growth.

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Quantitative assessment of cultivars for susceptibility was made. 'Bonanza' had a high incidence of rust and severe defoliation.

'Pink Quartet'. 'Dark Eyes', 'Mission Bells' and 'Groovy' had medium incidence of rust and defoliation while 'Tuonella', 'Easter Bonnet', 'Pink Fairy', 'Winston', and 'Churchill' had rust affecting 3 to 5 leaves but little defoliation.

'Party Frock', 'Pixie', 'Voodoo' and 'Lord Byron' had rust affecting leaves but no defoliation.

With home gardening, rust is only a problem in fuchsias late in the growing season or during wet weather. A relatively simple control is to prune and destroy infected tissue.

In nurseries its effect on presentation and general health of the plant is of extreme commercial importance. Despite culling of the more susceptible cultivars, rust continued to be a problem of substantial consequence causing a reduction in sale value.

The advised control for fuchsia rust was Plantvax 75 w.p.; commercial dosage, 1.7 gm/l. This was used with adequate success in the 1980 growing season.

However, in the following year lesser control was obtained and plant quality suffered. It was subsequently advised that double strength Plantvax be used. This controlled the rust, however an unsightly deposit was left on the plants, lowering commercial appeal.

I decided to test Baycor 300 E.C. Its active constituent is bitertanol 300 g/l from the group of triazole fungicides, which are ergesterol inhibitors. It is of low toxicity to man and fish and has a recommended rate of application of 1.7 ml/l.

In reply to my request for information on conducting trials the importance of a logical approach was stressed to me. I was advised to define clearly —

1. The Aim.
2. The Reason.
3. The Method.

This involved — (a) how to do the work; and (b) how to assess the results.

MATERIALS AND METHODS

Firstly, tests were made on the phytoxicity of the product at ½, 1, and 2 times the recommended concentrations on all the cultivars available at that time, namely Bonanza, Display, Jube-lin, Fifi, Tuonella, City of Pacifica, Red Radar, Mrs. Rundle, Party Frock, Lord Byron, China Rose, Harbour Bridge and Jazz. These tests were carried out during the late seasonal

growing time and, in spite of high humidity and high temperatures, no phytoxicity was observed.

(i) **Selection of Plants**

Sixty already rust-infected plants of the highly susceptible Bonanza cultivar were graded into groups according to severity of infection and then randomised into 4 treatment groups of 15 plants each. Plants were grown in the open on a well-drained site. Pots were placed on black ground plastic and watered with Pope butterfly type sprinklers. Spray was applied by a Rega hand pump.

(ii) **Spray Treatments**

Plants were sprayed to run-off 4 times at ten day intervals and were protected from overspray. Treatments used were Baycor 300 E.C. (1.7ml/l); Plantvax 75 w.p. (1.3gm/l) and 2.6gm/l); and an untreated control. No surfactants were used.

(iii) **Assessment**

Assessments were made between 10 and 18 days after treatment. The main method used was visual grading from 0 (no infection) to 5 (maximum infection). Two observers acting independently rarely differed in their assessment of individual plants.

Other assessments were leaf drop, flower number, and area of pot covered.

RESULTS

The severity of rust infection in the untreated control plants remained relatively constant (Table 1). Baycor sprayed plants had less infection than those treated with either single or double strength Plantvax. The mean unweighted percentage control was Baycor, 75%; Plantvax x 1, 20%; and Plantvax x 2, 51%.

Baycor gave better control of fuchsia rust when assessed by extent of defoliation, number of flowers, or area of pot covered (Table 2).

Table 1. Effect of fungicide sprays on severity of rust infection of fuchsia 'Bonanza' as measured by visual rating.

Date of Spraying	Treatment Date of Observation	Untreated	Baycor	Plantvax x 1	Plantvax x 2
Dec. 29	Jan. 8	3.4	3.4	3.4	3.4
Jan. 8	Jan. 25	2.8	0.7	1.6	2.1
Jan. 25	Feb. 4	3.0	1.6	3.0	1.3
Feb. 4	Feb. 14	3.0	0.6	2.7	1.3
Feb. 22	2.7	0.2	1.9	0.9	

Table 2. Effect of fungicide sprays expressed as percent of controls on severity of rust infection of fuchsia 'Bonanza'.

Treatment	Defoliation	Number of Flowers	Area of Pot Covered
Untreated	100	0	0
Baycor	4	68	70
Plantvax x 1	69	23	15
Plantvax x 2	17	58	45

DISCUSSION

The results given above show that irrespective of the method of assessment, outbreaks of fuchsia rust can be safely and significantly reduced by treatments at 10 day intervals with Baycor fungicide.

CITRUS NURSERY PRACTICES IN HUNAN PROVINCE, PEOPLES REPUBLIC OF CHINA

PETER B. SMITH

Sunraysia Nurseries
Gol Gol, New South Wales 2739

My observations are limited to the Central Southern Province of Hunan, latitude approximately 26°N. Citrus is also grown in a number of neighbouring provinces having a similar climate.

Historical records indicate citrus culture began in China about 4,000 years ago and was widespread by the Qin and Han periods, (221 BC to 220 AD). Changsha, the capital of Hunan Province, is the site of an archaeological find of great importance to the citrus world. Seeds of a citrus species were unearthed in a 2,100 year old tomb.

Citrus research was accelerated after the establishment of the Peoples Republic of China in 1949. However the cultural revolution of the 1970's was responsible for the destruction of vast areas of citrus orchards as citrus was then regarded as a revisionist fruit.

The census figures of 1980 show that China had 180,000 hectares of citrus planted of which 67,000 hectares was bearing. Production reached 797,000 tonnes in 1981. The production per hectare figure of less than 12 tonnes is extremely low by Australian standards.

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Climate, soils, and topography. The climate, in the region to which my observations are limited, is one of very cold winters with light snowfalls and very hot humid summers. The extreme minimum temperature recorded is −7°C and the extreme maximum is 39.8°C. January is the coldest month with a mean temperature of 5.9°C while July has a mean temperature of 29.1°C. The mean annual rainfall is 1,423 mm (57 in.) and the monthly mean hours of sunshine is 136 hours, approximately half that of the citrus region in Gol Gol, New South Wales.

Soils are medium and appear to be free draining and well aerated. The natural red soils are acidic with acidity increasing with depth. A typical profile for a natural soil was given as:

Depth (cm)	pH
0 - 20	4.2 - 4.5
20 - 40	3.8 - 3.9
40 - 60	3.6

NURSERY PRACTICES

(a) *Scion material*

The main cultivar grown, due to its cold hardiness, is a Satsuma type mandarin named 'Wenzhou Mikan.' Research is being conducted in China to select early maturing clones with above average fruit quality and bearing ability. Virus clean mother trees are not as yet being maintained and, in general, budwood is not being selected from specific clonal cultivars. Some sweet orange and some other mandarin cultivars are grown. Observations are being carried out at research institutions on these cultivars for cold tolerance, cropping levels, etc. Virus indexing and the establishment of selected mother tree plantings commenced in 1983.

(b) *Rootstock material and management*

Poncirus trifoliata is the only rootstock being used. The advantages of cold tolerance, resistance to nematodes, resistance to root rotting fungi and suitability to heavy loams is widely recognised. Seed is not selected from specific clonal cultivars although work commenced along these lines in 1983.

Trifoliata seed is extracted during mid- to late-October. Most nurseries over-winter seed by sowing in early November in open seed beds. The beds are prepared with the incorporation of organic matter. Seed is broadcast, covered with light dressing of sandy soil and the bed is then covered with a layer of organic matter to conserve warmth and moisture. In the

1982-83 season some 10% of seed stored in this manner germinated early and was killed by winter frosts.

An alternative method of seed storage is to blend it with moist sand and store at room temperature (approx. 4°C to 10°C). However, it is considered that losses due to rodent and fungal damage are greater than those experienced when seed is sown in November.

Pre-germination is often practised when seed is spring-sown in beds of the same preparation as previously mentioned. Stored seed is moistened, placed in plastic bags, and plunged into composting heaps of organic matter. Temperatures are monitored to maintain a constant 25°C with germination commencing in 4 to 7 days. The seed is again broadcast and covered with sand and organic matter. Low plastic tents are erected on bamboo sticks to conserve warmth within the seed bed.

Due to high rainfall in spring inhibiting field work, most propagators favour autumn transplanting of seedlings to nursery rows. However, some spring transplanting is practised.

There is a great variation in spacing plants in nursery rows, as no mechanical aids are used. In general, nursery trees are grown much closer together than in Australian nurseries, the average planting distance being 30 to 60 cm between rows and 7 to 10 cm between plants.

(c) *Budding techniques*

Autumn budding during September, using a normal "T" bud tied with plastic budding tapes cut from sheets, is the practise of all nurseries visited. Success rates of 90% are expected. Buds are inserted very low — 4 to 8 cm above ground level.

Stocks are cut back to the bud in spring. Lopping or bending of stocks to force the bud is not practised, and misses are side bark-grafted in March.

(d) *Nursery management*

All planting, cultivation, and lifting is done by hand. Trees are produced in 3 to 5 years from seed sowing. Scions are not staked or headed; however they are trained to a single rod for the first 20 to 30 cm of growth. Orchards are all hand-worked hence there is currently no need to train trees to a high single trunk.

Little attention is paid to nursery hygiene. No soil sterilisation is practised and nurseries are not fenced. Both red and rust mites abound together with leaf miner and a vast array of scale insects. Trees are not insecticide treated in any way prior to dispatch.

CONCLUSIONS

There is a great need to modify nursery practises in every aspect to produce trees for Chinese orchards of the future. Both stock and scion selection of existing and newly introduced cultivars is of paramount importance. This work has now begun. The establishment of virus-free mother tree plantings of selected clones, and their constant monitoring, is also underway.

Nursery hygiene and tree training to accommodate mechanized orchard management is a new concept now being demonstrated, together with all of the inherent benefits of container-grown tree production.

TOWARD A WORKABLE SOFTWOOD CUTTING TECHNIQUE FOR PROPAGATING AVOCADOS

T. TROCHOULIAS,

Tropical Fruit Research Station, Alstonville, New South Wales

G.W. GRIFFITH and N.G. SMITH

University of New England, Armidale, New South Wales

Abstract. Comparisons were made of the rooting responses of cuttings taken from terminal flushes of 'Duke 7' avocado which were stimulated by wire constriction, etiolation, marcottage, and combinations of these treatments. After seven weeks the treated terminal shoots were removed from the parent tree and placed in a peat-vermiculite mix in 125 mm pots under mist. Only seven cuttings with wire constriction, etiolation, and marcottage, or a combination of them, produced roots after 57 days. All cuttings produced a vegetative flush within 8 to 16 weeks.

INTRODUCTION

Avocado trees are usually propagated by grafting proven scion cultivars onto avocado seedlings, which are very heterozygous. Recently there has been interest in using vegetatively propagated rootstocks, particularly from the Duke 7 cultivar which has shown moderate resistance to *Phytophthora cinnamomi* (9). Frolich (5) pioneered the "etiolation technique" for vegetatively propagating rootstocks and this has been modified and patented by Brokaw (4). The modified technique involves the following basic steps:

a) A scion of the rootstock cultivar is grafted on to a nurse seedling.

b) A girdling ring is fitted over the intermediate rootstock and the grafted plant is etiolated for one month.

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b) A girdling ring is fitted over the intermediate rootstock and the grafted plant is etiolated for one month.

c) An enclosing black bag is raised, more potting mix added and the desired commercial scion cultivar grafted onto the rootstock scion (double graft).

d) The rootstock makes roots assisted by nutrients from the nurse seedling until the girdling ring constricts further development and the intermediate rootstock takes over completely.

e) The section below the ring sloughs off.

f) The scion develops and the desired cultivar on a clonal rootstocks is ready for planting out in 18 months.

A more conventional approach is to use cuttings under mist. Ben-Ya'acob and Kadman (2) showed that soft cuttings of avocado usually rooted faster than semi-hardwood cuttings, although soft cuttings were more prone to disease attack. In contrast, Assaf (1) and Bourdeaut (3) showed that semi-hardwood cuttings gave the best rooting. Reuveni and Raviv (8) found that the rooting percentage was correlated to the number of leaves retained by the cuttings.

No information is available about the establishment of scion cultivars grafted onto disease-resistant rootstocks propagated from cuttings. This experiment was carried out to assess the effects of various pre-treatments on cuttings of the *Phytophthora cinnamomi* tolerant rootstock, Duke 7, and the subsequent growth of plants from these cuttings.

MATERIALS AND METHODS

A single 6-year-old Duke 7 seedling tree from clonal Duke 7 was chosen at Tzana Farm, Alstonville, New South Wales (29°S). The following treatments were applied at random to branches of the parent tree and replicated 10 times.

1) Control

2) Wire constriction

3) Etiolation

4) Wire constriction + etiolation

5) Marcottage + wire constriction

6) Marcottage + stem wounding

7) Marcottage + wire constriction + stem wounding

In the wire constriction treatment pliers were used to place a single strand of 1 mm copper wire tightly around the penultimate flush of terminal growth. Black electrical tape was wound tightly around 6 cm of stem to effect etiolation.

Wounding was effected by means of a slanted cut 1 to 2 cm long cut half way through the stem and kept apart with a small stick dipped in No. 2 Seradix rooting powder.

Marcottage was applied with peat moss wrapped in black polythene.

After seven weeks treated shoots were removed from the parent tree and dipped in a 50:50 v/v mixture of Rite Grow No. 6 hormone rooting powder and Captan fungicide.

At the Tropical Fruit Research Station, Alstonville, these treated cuttings were placed in 125 mm red plastic pots under intermittent mist in a temperature modified glasshouse covered by 50% shadecloth and given bottom heat of 27 ± 1°C. The rooting medium of peat and vermiculite was adjusted to a pH of 6.5 with the addition of lime.

The cuttings were assessed for root development at 32 and 57 days. After eight weeks cuttings with root development were potted into 140 mm red plastic containers. Two grams of Osmocote (NPK 19:2.6:10) which releases nutrients over a 3 to 4 period were added to each container. Finally, the time to complete the first flush of growth was recorded.

RESULTS AND DISCUSSION

Five cuttings with wire constriction, etiolation, and marcottage — or a combination of them — produced roots within 32 days which is comparable to that reported by Moll and Wood (7). By 57 days another two cuttings produced roots (Table 1). However the breakdown of the temperature regime in the glasshouse when ambient air temperatures reached 36° to 38°C for three days in mid-summer caused some mortality. Despite this a total of seven cuttings which had produced roots within 57 days went on to complete a flush of shoot growth within 8 to 16 weeks after being potted into 140 mm pots.

It is stressed that excellent root systems were formed on cuttings from shoots that had been both etiolated and wire constricted. By contrast, when only one of those treatments was given to the shoots, no roots formed on the derived cuttings.

Further experiments are required to establish the reliability of a wire and tape pre-treatment for rooting cuttings. Scion cultivars would have to be grafted onto these cuttings and greater growth rates achieved than in the technique described by Brokaw (4).

Table 1. The number of 'Duke 7' cuttings forming roots in 32 and 57 days in response to treatments and the time taken to complete the first flush (adapted from Griffith (6)). Each treatment involved 10 cuttings.

Treatment	No. of days under mist: 32	57	No. of weeks to complete first flush
	No. of cuttings with roots		
1) Control	0	0	
2) Wire constriction	0	0	
3) Etiolation	0	0	
4) Wire constriction + etiolation	2	3	8, 10, 13
5) Marcottage + wire constriction	1	1	13
6) Marcottage + stem wounding	0	1	16
7) Marcottage + wire constriction + stem wounding	2	2	14, 16

Acknowledgement. We wish to thank Mr. I Musgrave for technical assistance.

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PROPAGATION OF *DRACAENA MARGINATA* BY HEADS

ADRIAN HICKS
Hicks Brothers Nursery
Southport, Gold Coast, Queensland

Dracaena marginata is easy to propagate from large stems taken from established trees by placing them in double washed river sand in a 3 gal tub under shade and watering once a day for a period of 10 to 12 weeks. However, not only does this method ruin your tree but if done in the winter, between April and September, will kill it. Also there is very little of this mature stock around.

My method is to peel off 8 to 12 leaves from the centre of the head, leaving 10 to 12 leaves below the bared stem section. This leaves a nice, bushy head with mature wide leaves. This is left alone for several weeks until the bark has hardened like the mature wood on the bottom.

The heads are then cut off with a small saw and 5 or 6 are placed in a bucket with a small layer of sphagnum moss for 24 hours until the sap has dried out. The leaves are watered a couple of times to stop dehydration.

The heads are then planted in double washed river sand in a 1 or 2-gal bucket. After 5 to 6 weeks in a bush-house or in shade they will have struck roots. I came to the conclusion that the softness of the outer bark and the sap had killed my previous heads.

A few weeks after cutting the heads from the parent tree I had 2 or 3 nice new heads sprouting for next year, whereas by taking the whole branch near the base I was cutting off my stock for next year. This way I end up with a nice shaped stock plant which, if it is in the ground, can be dug and potted after 7 or 8 years, sold for a good profit and replaced with a smaller tree.

SUMMER GRAFTING OF GOLDEN ROBINIA

GRAHAM PARR
Kenthurst, New South Wales

Robinia pseudoacacia 'Frisia' (golden robinia) is a small to medium, fast-growing, deciduous tree of the Leguminosae family. It has golden-yellow leaves from spring to autumn and white wisteria-like flowers in spring.

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The heads are then cut off with a small saw and 5 or 6 are placed in a bucket with a small layer of sphagnum moss for 24 hours until the sap has dried out. The leaves are watered a couple of times to stop dehydration.

The heads are then planted in double washed river sand in a 1 or 2-gal bucket. After 5 to 6 weeks in a bush-house or in shade they will have struck roots. I came to the conclusion that the softness of the outer bark and the sap had killed my previous heads.

A few weeks after cutting the heads from the parent tree I had 2 or 3 nice new heads sprouting for next year, whereas by taking the whole branch near the base I was cutting off my stock for next year. This way I end up with a nice shaped stock plant which, if it is in the ground, can be dug and potted after 7 or 8 years, sold for a good profit and replaced with a smaller tree.

SUMMER GRAFTING OF GOLDEN ROBINIA

GRAHAM PARR
Kenthurst, New South Wales

Robinia pseudoacacia 'Frisia' (golden robinia) is a small to medium, fast-growing, deciduous tree of the Leguminosae family. It has golden-yellow leaves from spring to autumn and white wisteria-like flowers in spring.

Golden robinia is grafted onto seedlings of *Robinia pseudoacacia* (black robinia). As most deciduous tree grafting is done during winter I, at first, did mine at this time. However, I noticed my understock was large enough to graft by midsummer (December). I knew this was a good time for budding so why not grafting? I tried grafting some trees as an experiment and was amazed by the good results.

I do my grafting in pots which are 85 mm in diameter and 150 mm deep. This gives good soil volume and allows a large number of pots per square metre. Handling is kept to a minimum by using pallets that are 1.24 m by 1.33 m and hold 263 pots.

Preparation of Understock. From 3 to 8 seeds are sown directly in each pot and placed in a polyhouse in early August (late winter). They germinate in 10 to 15 days and the excess seedlings are cut off at ground level with scissors. More seed will germinate in the next 15 days and another thinning is necessary. After two weeks, when the seedlings are about 75 mm tall, the pallets are taken from the polyhouse into the shadehouse. They are left to grow until mid-December (early summer) when the average height is 600 to 800 mm. The plants are then taken into a shed and bench grafted. Plants that are not large enough to graft at this time can be returned to the growing area to be grafted in winter.

Preparation of Scion Wood. As it is summertime, the scion wood is in leaf. Healthy, 4-month-old branches about 30 cm in length are preferable. I remove the leaves while the wood is on the tree. This reduces the chances of the wood drying. The terminal 4 or 5 buds, which are too soft, are removed while deleafing. Enough wood to last one day at a time is collected in the early morning and wrapped in wet newspaper.

Grafting. I use the top cleft or wedge graft method (Figure 1-left) as I consider it is the easiest graft to do. The understock varies in diameter from 4 to 15 mm (8 to 10 mm is ideal); however the success rate drops with understock less than 6 mm in diameter.

Scionwood is best if it is the same diameter as the understock but this is not always possible. If the scion is thinner than the understock, the wedge can be tapered on one side (Figure 1-right). Thus when it is inserted in the graft, it makes a tight connection on the cambium layer (Figure 2-left). If a parallel wedge is made, there may not be cambium connection after tying (Figure 2-left).

If the scion is larger than the understock the wedge can be cut down to size (Figure 2-right).

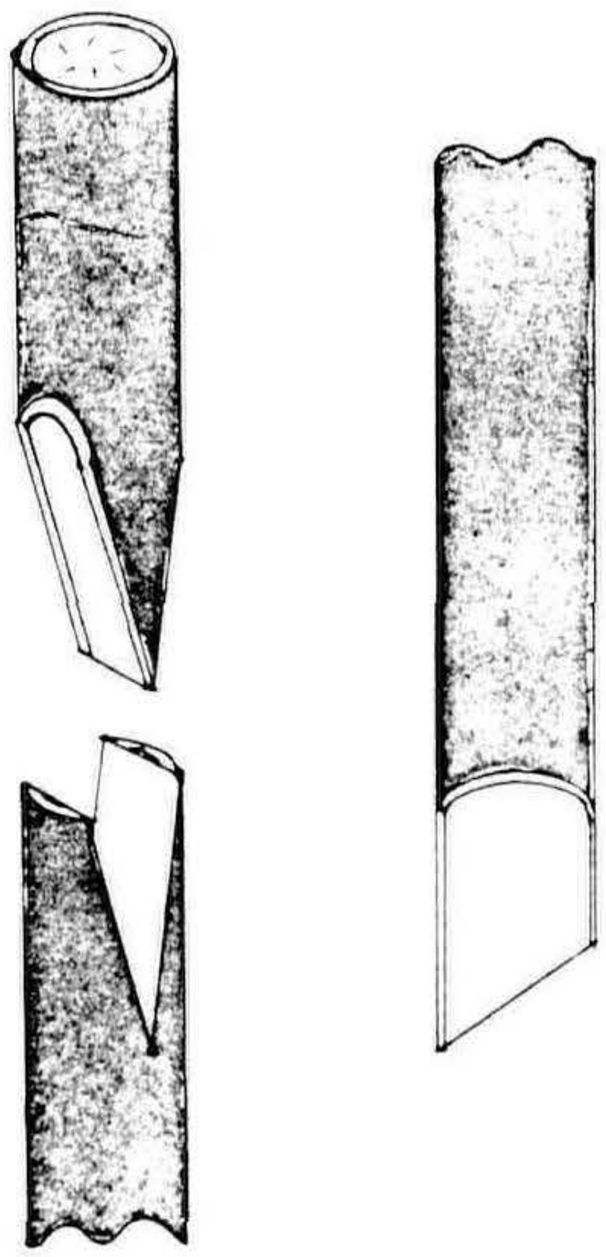

Figure 1. *(Left).* Cleft or wedge graft. *(Right).* Modified wedge graft for a scion that is thinner than the stock.

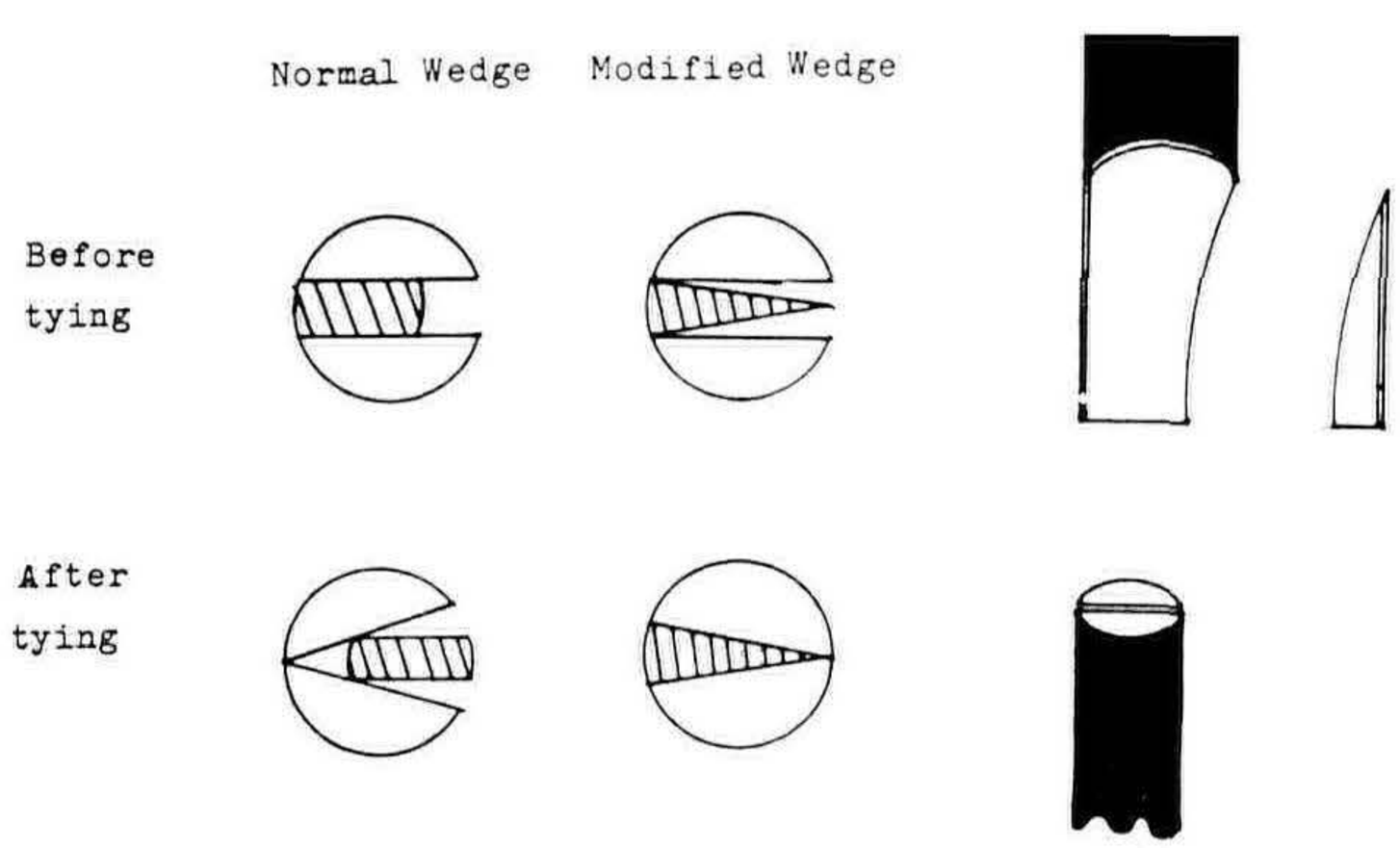

Figure 2. *(Left and Center).* Effect of the modified wedge graft in ensuring cambial contact after tying. *(Right).* Modified wedge graft for scion that is larger than the stock.

Note the position of the bud in Figures 1 and 2-right. I generally use only one bud for the scion, as scionwood is usually scarce and has to be used economically. This year I did a trial using 2-bud scions. A marginally better success was noted but more labour was required at a later date to reduce it to a single shoot and so produce a single-stemmed tree.

The plants are placed in the glasshouse after grafting. Within 10 days most buds are swollen ready to shoot and within 20 days all buds that will shoot have done so. It is necessary to go through and cut off any suckers at 30 days. At 50 days the plants are moved into the shadehouse where they are potted into 250 mm buckets; any suckers are cut off at 60 days. The plants should be 300 to 450 mm high before dormancy and will grow very quickly when spring comes.

CONCLUSION

I find that by doing my grafting in summer the plants are ready for sale in early spring, which is the best time for selling plants. This means that the plants are ready for sale after 14 months and will sell very well at this stage. When they are grafted in winter, the understock are 12 months old when grafted and are ready for sale 4 months later. This is now 16 months and January (mid-summer) which is a quiet time for sales. Therefore, the plants won't sell quickly until the following spring — another 8 months. This gives an effective growing time of 24 months — almost twice that of summer grafting.

A SIMPLE METHOD FOR IN-GROUND PRODUCTION OF SEEDLINGS

K. HOLMES

Northolme Nurseries Pty. Ltd.
153 Newell Street, Cairns, Queensland 4870

The method discussed here has been used successfully for growing vegetable and flower seedlings for many years. It could be used to grow a wide range of shrub, tree, and creeper plants. This method may be of particular interest to people who wish to grow large quantities of material.

The soil should be a light loam in texture, rich in the essential nutrients, and worked to a fine state by rotary hoeing. It should be sterilized with methyl bromide or some other method, be raked as evenly as possible and should be in a moist state.

The wooden drill-making implement (Figure 1) is pressed into the loose soil surface firmly and when removed will leave seven (7) drills approximately 10mm deep. The bed is now ready to plant.

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The wooden drill-making implement (Figure 1) is pressed into the loose soil surface firmly and when removed will leave seven (7) drills approximately 10mm deep. The bed is now ready to plant.

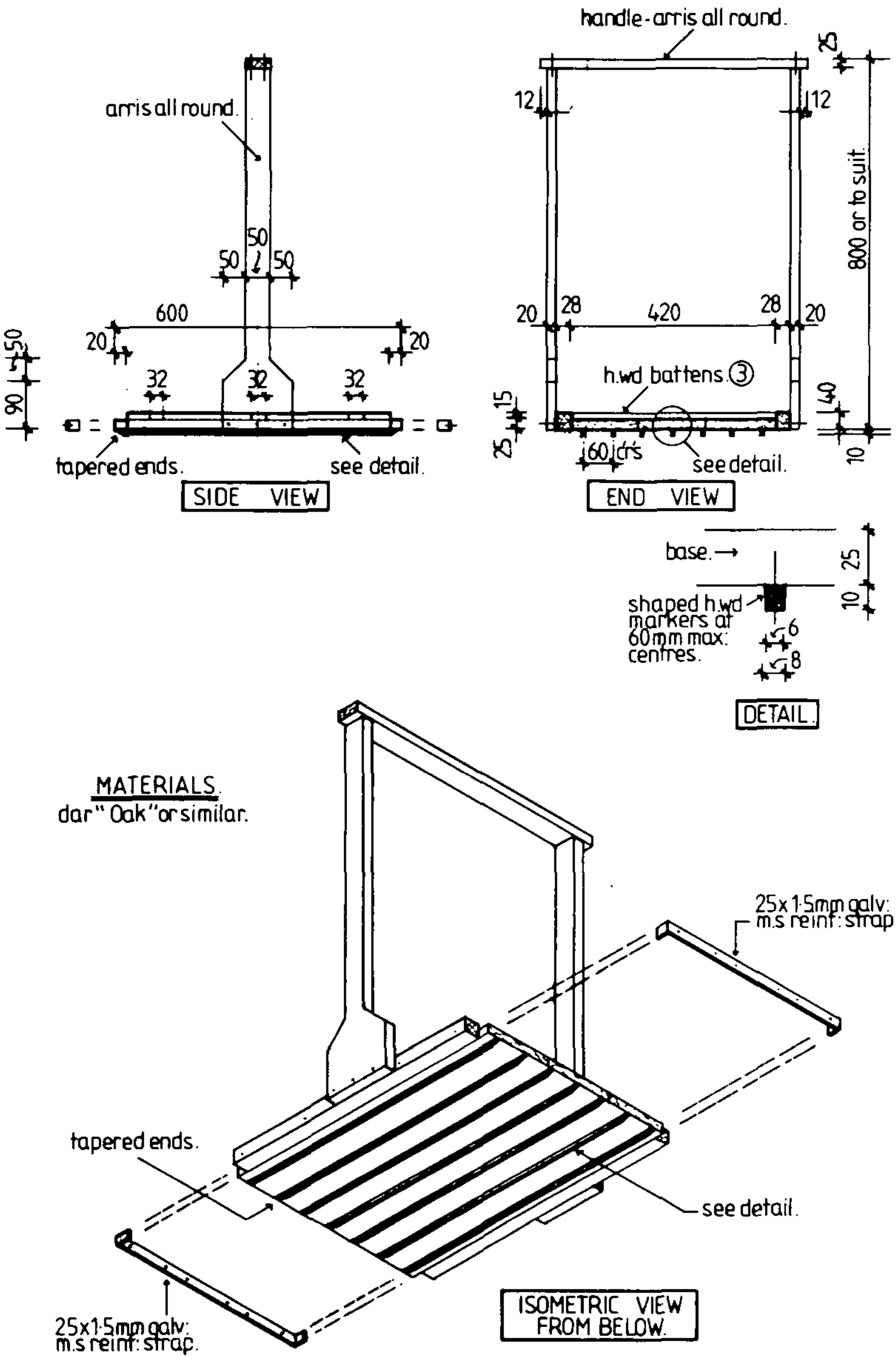

Figure 1. Diagram of drill-forming implement, the Northolme Nurseries Pty. Ltd. seed furrow presser.

Planting is done using the forefinger and thumb. The seeds are planted into the prepared drills as thick or thin as needed. When the planting is completed, a light covering of a moisture retentive material is sieved over the seeds. The thickness of the covering depends on the seed size, very small seeds need only the lightest covering while more covering is applied to large seeds, but only to the extent that they are just covered and no more.

Materials for sieving onto the seeds could range from vermiculite or peat moss to old sawdust or old horse manure. It must of course be sterilized.

The planted bed is watered with a spray of water fine enough that it will not move the seed when well wetted.

A pipe frame of ⅜ in. galvanised pipe covered with 50% shade cloth is then placed over the beds. This allows watering through the cover. The frame is removed one day after the seed has germinated to avoid etiolation.

A wide range of seed sizes can be planted into the 10 mm drill. Seed sizes range from the petunia seed, which can be compared with *Leptospermum* seed in size, to lupin seed which can be compared with *Cassia nodosa* in size. The important factor is in the rate of application of the material used to cover the seeds. In all cases the covering material needs only to cover the seeds and no more.

Advantages of this seed planting method are:—

(1) Unskilled staff can learn to plant quite easily.

(2) It is relatively easy to control plant thickness.

(3) Plant counting is easier when planted in rows.

(4) Root pruning, if necessary, is easily achieved by planting in rows.

Disadvantages of this seed planting method are: —

(1) Slow planting rate as compared to broadcasting.

THE ROLE OF PLANT PROPAGATION IN TAXONOMY AND CONSERVATION

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Some knowledge of the fantastic diversity of plants and animals that we call "natural variation" has been of critical importance to mankind throughout the course of his history: which plants can be eaten and which must be avoided; which animals were prey and which were predator; which drugs will cure and which will kill. Because life often depended on some rudimentary degree of this quickly learned classification, taxonomy must be considered a very old profession.

With literally millions of species of plants and animals now known to science, one might think that all biological diversity would have been accounted for and that taxonomist would have long ago closed up shop. Quite the contrary. With new analytical tools, new advances in genetic correlation, and new pressures on the few undeveloped portions of the world that still contain many undescribed species, taxonomists still have work to do.

The title of my paper suggests the question I wish to address: "What role does plant propagation play in this work of plant classification and conservation?" As we attempt to answer the question, it must be kept in mind that, because of differences in personal and professional view-points concerning the concepts of taxonomic categories and the stability of plant names, both plant taxonomists and plant propagators themselves are often a major part of the problem as well as part of the solution.

If we attempt to summarize the total scope of biological diversity, we will find that despite the previously mentioned millions of species of plants and animals, we can go further: there are subspecies, varieties, forms, hybrids, cultivars, and, for many plants, named horticultural varieties. Indeed, it is quite likely that natural variation is so great that no two individual organisms on earth are really identical; each will vary in some way from all other organisms, even of the same species, because of some degree of difference in size, shape, color, physiology, chemical constituents or, if nothing else, in number of cells — or cell organelles. Such incredible variation is, of course, the result of certain genetic changes (i.e. mutation and recombination) and the constant interaction of the genetic system of an organism with the environment in which the organism exists.

Mutation, or genetic change at the codon or higher level, is the only source of actually new genetic material and, at least in terms of ultimate expression, is a rather rare event. Extensive historical studies in corn *(Zea)*, fruit flies *(Drosophila)*, and a few other experimental organisms provide a basis for an "average" mutation rate for a particular gene of one per 100,000 duplications. However, if we are to consider the total range of actual and potential variability that provides the array of forms of life, it might be instructive to look at mutation in a more appropriate context — namely in terms of the total production of male and female gametes rather than as a mere arithmetic ratio. Here the picture seems to change.

If we assume (again from experimental work) that an organism has 10,000 genes, and if all genes are assumed to have the same "average" mutation rate of 10^{-5}, one gamete in ten should have one mutant among its 10,000 genes. Thus if a single population of plants or animals produced only 1,000,000 gametes per breeding cycle, there could be 100,000 mutant gametes produced, or an equivalent of ten new mutant alleles for each of the 10,000 original genes! However, in reality, gamete production is much higher. A class study of a colorful, common fall weed of southeastern U.S., *Bidens aristosa* of the Asteraceae, provided some interesting average figures on gamete production in a single population of these plants covering only 40 square meters: there were 16 plants per square meter; there were an average of 25 heads, or inflorescences per plant with an average of 40 flowers each; there were five anthers in each flower and an average of 1500 pollen grains per anther. Thus if we multiply this out (40 square meters $\times$ 16 plants per square meter $\times$ 25 inflorescences $\times$ 40 flowers $\times$ 5 anthers $\times$ 1500 pollen grains), we find that the 3,200,000 anthers produce 4,800,000,000 males gametes. With our previous figure of 10,000 genes per genome and a mutation rate of 10^{-5}, there would be nearly 500,000,000 mutant gametes produced in this one small population of *Bidens!* Fortunately no organism reaches its full reproductive potential; for one reason or another (inlcuding mutation) most of these gametes never function. However, there is a tremendous potential for variation through mutation in even small populations of organisms, and this potential is further enhanced by the gentic recombination that results from sexual reproduction, especially among outcrossing organisms.

Environmental factors — temperature, light, humidity, nutrients, competition, and predation — to list a few — interact at every stage of the organism's growth and development to further attenuate the actual degree of natural polymorphism that tends to keep both the taxonomist and the plant propaga-

tors in business — provided each new variant can be more or less consistently recognized, described, named, and catalogued or sold. And this brings us to the point concerning conservation.

Many of the biologically or aesthetically interesting plant variants, often called "freaks of nature" when they occur naturally but "the product of an extensive breeding program" when the result of a few lucky hybridizations and a bit of artificial selection, are, by the very nature of their creation, either rare or uncommon. Thus both their morphological differences and their rarity tend to give such plants added monetary value as well as scientific interest. Such added value or interest may, especially in the case of natural variants, lead to their extinction. On the other hand, if a mutant, hybrid, or other natural variant has sufficient cultural significance, fiscal value, or popular interest, these factors may, indeed, result in the conservation rather than the destruction of the varient plant.

For example, natural populations of a number of well known horticultural plants, such as *Ginkgo* and *Franklinia*, are unknown and the species survive only through the efforts of plant propagators. Many other species, such as *Rhododendron vaseyi* and *Shortia galacifolia*, to name two native to the southeastern U.S., occur naturally in only a few small, local endemic populations but are widespread and well known as horticultural plants and thus are in little danger of actual extinction.

Countless other variants have not been so fortunate. For example, *Lysimachia salicifolia*, first described by Ferdinand Mueller in his 1869 "Flora Australiensis", has appeared again only in print — in 1905 in Das Pflanzenreich and more recently (1972) in "A Handbook to Plants of Victoria" by James Willis. This last reference contains the annotation " . . . only a single, inadequate Victorian collection is known, made at the mouth of the Snowy River by F. Mueller in Feb., 1855 — it has long since been presumed extinct in that locality." The question, of course, is: was this truly just a single "freak of nature" such as a hybrid or a mutant, or a rare but real "taxonomic entity", or perhaps just an overstretched figment of a fertile taxonomic imagination? If the plant had been propagated (which of course was neither practical nor possible at that stage of floristic work in Australia) it is possible that we might some day learn the answer. Now we can only guess.

By way of illustrating the role of plant propagation on a somewhat more happy taxonomic scenario, I would like to follow the taxonomic and horticultural history of a few plants in the interesting genus *Sarracenia*, a small group of 8 to 10 species of herbaceous, rhizomatic, perennial, insectivorous (or

"carnivorous") plants native to the moist savannas of the southeastern United States. As with all carnivorous plants, these have had periodic attention from the public press and are of continuing commercial value around the world.

The hollow, often water-filled leaves of these plants were noted by the earliest botanical explorers and the first accounts of them reached Europe in 1586 with Bannister's report on Carolina plants. The first actual specimens of these plants to reach Europe seem to have been sent from Canada by Dr. Sarazin, for whom the genus is named, about 1650. A century later Mark Catesby included a plate of *Sarracenia purpurea* in his "natural History of Carolina, Florida, and the Bahamas". This drawing, cited by Linneaus in his 1753 description of the genus, has been designated as the lectotype of the species. So let us start our review with *Sarrancenia purpurea*.

At one time *Sarracenia purpurea* occurred over much of eastern North America and is the most widespread of the species with considerable genetic and phenotypic variability. Flower color, for example, may range from very dark maroon for plants in full sun to very pale pink (with white style discs!) for plants in deep shade. If plants of either of these color extremes are transplanted to more moderate light, the flower color becomes, in subsequent years, more uniform and characteristic. Anthocyanin-free mutants of *S. purpurea*, with clear yellow flowers and no trace of red in the leaf veins, are known in Nova Scotia, near the northeast limit of the plant's range, and also in Michigan, some 1,000 miles inland near the northwestern edge of the range. There is, of course, no modification of color intensity in these plants under changed light conditions. Despite this range of color variation, *S. purpurea* has a number of distinctive qualitative features, especially in the leaves: an erect, wide, hood with stiff, downward pointing hairs; an exposed orifice; red veins and nectar area but no white spots or other markings and a short, fat "pitcher".

Sarracenia flava, the second species described by Linnaeus, has stronger scented flowers with rich yellow petals, tall, erect, evenly tapered leaves (often of considerable size and digestive capacity!), with a glabrous, somewhat horizontal hood, partially covering the leaf orifice. *Sarracenia flava* is found only in the southeastern U.S. and color variation in the leaves, which is obviously genetic as shown by the different clones in this population, has no effect on flower color — no maroon flowered plants of *S. flava* have ever been reported.

Sarracenia catesbaei, was described as a new species by Stephen Elliott in 1824 in his "Sketch of the Botany of South Carolina and Georgia", on the basis of some plants collected in

South Carolina by a Dr. MacBride. Subsequently the plant's identity was thoroughly confused: in Eaton's Manual of Botany (1836) the plant is considered a species, *S. catesbaei*; Croom (1848) considered it "hardly a variety of *S. flava*; Decaisne (1851) named it under *S. flava*; later the name *S. flava* subsp. *catesbaei* was used by Mohr (1897) to refer to some plants growing along Little River in northeastern Alabama; Mohr (1901) soon raised these plants to specific rank and, thinking them to be distinct from *S. flava* and similar to those described by Elliott, called them *S. catesbaei*; Harper (1903) incorrectly applied the name *S. catesbaei* to some hybrids between *S. leucophylla* and *S. flava*; in an article on the history of *S. catesbaei*, Macfarlane (1904) considers the name to apply to the atypical *S. flava* growing around Mobile, Alabama, plants which today are recognized as constituting the species, *S. alata*. What was the problem? No other name in the genus has had such a varied history as *S. catesbaei*. The answer came from the work of the English plant propagators and hybridizers: *S.* × *catesbaei* is a natural hybrid. When MacFarlane (1908) monographed the genus *Sarracenia* for Das Pflanzenreich, he recognized the hybrid nature of *S.* × *catesbaei* and described the Mobile plants as a new species — *S. sledgei* (now *S. alata*). Mohr's plants from along Little River were placed under *S. flava* by MacFarlane (1908), and were not recognized and properly described as a distinct species until 1933, when they were described as *S. oreophila* by Wherry.

The first artificial *Sarracenia* hybrid to flower was exhibited and described in 1874 by Dr. David Moore of the Glasnevin Botanic Garden, Dublin. Although 4 to 7 years are required to raise a *Sarracenia* hybrid to flowering size, another artificial hybrid, *S. flava* × *S. purpurea*, was reported within a week. Hence, horticultural interest in these plants must have started around 1870. This interest increased until about 1886, when these plants lost general popularity as suddenly as they had gained it. The taxonomic and cultural information from this brief era of horticultural interest has, however, remained of biological and taxonomic importance to this day.

The morphology of *Sarracenia* flowers is equally as interesting as that of the leaves. The five stigmas are borne on the inner (recurved) surface of the expanded, flattened style disc which catches the pollen shed from the numerous anthers. Ants and other insects spread the pollen over the stigmas. The plants are self fertile and also hybridize easily. With the known parentage and careful descriptive work, often with illustrations, of the 19th century hybridizers and the fact that, in most instances, the hybrids are nicely intermediate between the parents, the likely parentage of most natural hybrids, and

even backcrosses or 3-way hybrids, can be ascertained on the basis of known qualitative and quantitative characters of the species, as illustrated in the following five natural hybrids:

S. rubra × *S. alata* = *S.* × *ahlesii*

S. minor × *S. psittacina* = *S.* × *formosa*

S. minor × *S. purpurea* = *S.* × *swaniana*

S. minor × *S. rubra* = *S.* × *rehderi*

S. leucophylla × *S. psittacina* = *S.* × *wrigleyana*

A beautiful color varient, an anthocyanin-free mutant of *Sarracenia rubra*, the sweet (fragrant) pitcher plant, is the most recent discovery of scientific and commercial importance in the genus. A few of these yellow-flowered plants were discovered in a bog in the mountains of western North Carolina about 10 years ago and were nearly wiped out by "collectors" within a year. From a single capsule we grew out 57 all yellow plants (which can easily be detected in the seedling stage). These plants are all now mature and blooming and providing more seed each year for further propagation. In time, we hope to have enough plants to offer for sale in the trade. At that time plants will also be available (as is now also the plan for the very rare *S. oreophila* also being grown from seed at the North Carolina Botanical Garden) for transplanting *back* into some of the more protected native habitats and the important role of plant propagation in taxonomy and conservation will have again been realized. Pitcher plants may never again be so common as to be collected by the van load, but neither will they become extinct.

EVALUATION OF COMMERCIAL MIST CONTROL UNITS

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Abstract. The performance of five commercially available mist propagation controllers were evaluated. Those tested were a cyclic timer with day/night switching, paper sensor (A.C. resistance), light sensor, resin block (capacitance) and relative humidity (temperature differential).

When properly adjusted and maintained all the units provided a constant moisture film over the test plants. There was no significant difference in rooting among plants on beds controlled by the various units. The most obvious difference among the units was the level of maintenance and the re-adjusting of required settings. Once installed and calibrated the light sensor and the relative humidity controllers required no further attention for the duration of the trial (6 weeks).

INTRODUCTION

The basic aim of cutting propagation is to maintain the material in a turgid state until roots form. Intermittent misting is a successful way of achieving this for a wide range of plants, especially during warm weather. It allows the cuttings to receive high levels of light yet to be maintained in a turgid state. It also avoids problems associated with continuous misting, i.e. excessive water usage and leaching.

This system maintains a thin film of moisture on the leaf by activating a high or low pressure misting system at regular intervals. Because of the frequent application of mist, e.g. every 10 minutes, some type of automatic controller is obligatory. The types of mist control units available, with some of their most important characteristics, are listed in Table 1.

Table 1. Mist Control Systems.

	Method of Operation	Maintenance	General Comments
		DIRECT SENSING	
1. *Conductivity*			
(a) Absorbent material (usually paper)	As paper dries out its resistance increases and activates mist at preset level	Change paper every 1-2 weeks depending on water quality	Not suitable for water that is dirty or high in salts
(b) Impervious (usually plastic) surface with electrodes	Measures directly the electrical resistance of moisture film on its surface. As film evaporates and the resistance increases to a set value mist is activated	Wipe every 1-2 weeks	Not suitable for water that is dirty or high in salts

Table 1. Mist Control Systems. (Continued)

	Method of Operation	Maintenance	General Comments
2. *Capacitance*	Measures thickness of moisture film on an impervious surface indirectly. When thickness falls below present level mist is activated	Wipe every 1-2 weeks	Less affected by salts or dirt than previous methods but still a problem
3. *Temperature*	Measures temperature difference between surface wetted by mist and wet bulb temperature. When temperature differential increases to preset level, i.e. top surface dries, mist is activated	Refill water container for wet bulb temperature as required (about once a month)	Not significantly affected by dirt or salts
4. *Weight*	Measures weight of water on a mesh by balance. As water evaporates and weight falls below a preset level, mist is activated	Clean every 1-2 weeks	Very susceptible to dirty water and algal growth. Less susceptible to salts. Must be protected from wind and draught
INDIRECT SENSING			
1. *Light*	As light intensity increases, frequency of misting increases	none	Sensor not affected by dirt or salts in water. Relies on evaporation rate being in proportion to light intensity. This is generally true for environmentally controlled glasshouses but does not take into account wind or relative humidity which vary considerably under outdoor or shade house conditions. Zero maintenance is a big advantage
2. *Thermostat*	As temperature increases to a preset level either mist is activated directly or via cyclic timer	None — but frequent attention to settings needed	Evaporation is generally less related to temperature than light. Usually poor accuracy. Setting may be needed to be adjusted frequently

Table 1. Mist Control Systems. (Continued)

	Method of Operation	Maintenance	General Comments
3. *Humidistat*	Directly measures relative humidity of air. When it falls (i.e. the plants dry out) mist is activated at preset level	None — but calibration may drift	Usually poor accuracy at the high relative humidities that are required. Not a precise method but relatively low cost
	TIMERS		
	Cyclic timer operates mist for short periods — may also have day-night/on-off facility (desirable)	None — but frequent attention to settings needed	Popular with some large operations due to reliability and direct control over mist. Cycle needs to be changed with varying environmental conditions. Tends to use more water than some other systems

Direct sensors attempt to measure the actual amount of water on a surface. The mist is activated when the surface dries to a predetermined condition ("set point"). This type of controller is generally the most successful in widely varying environmental conditions, but poor quality water can mean considerable maintenance will be required.

Indirect sensors measure some environmental parameter on which evapotranspiration (rate of water loss) depends, e.g. light, temperature, or relative humidity. The success of these sensors depends on how accurately they predict actual evapotranspiration. In a greenhouse, for example, potential evapotranspiration depends mostly on incoming radiation (i.e. light levels). However this relationship does not hold as closely in a shade house where wind and relative humidity may be more important.

It is very important that the positioning of sensors for both types be representative of greenhouse conditions. Often large gradients in light, temperature, and relative humidity exist, especially on hot days when proper functioning of the mist control system is the most important.

The success of timers depends on the skill of the propagator who controls the timing interval. For example, if the plant material becomes too dry the misting frequency must be increased by the propagator. The biggest disadvantage of this type of controller is the level of attention required, especially during changing weather conditions. Both indirect sensors and timers have the advantage that they are not affected by water quality.

The study reported here examined the performance of commercial mist control units selected from each of the three groups of controllers.

MATERIALS AND METHODS

A comparison of the mist control units was conducted starting 1st September 1982 (spring), initially for a 6 week period, in a plastic double-skinned greenhouse at the Horticultural Research Station, Gosford, N.S.W. The greenhouse had 60% shade with a minimum temperature of 18°C and a maximum of 27°C over the first 6 weeks of the trial. Cooling was via a ducted evaporative cooler. Light intensity on the mist beds used to evaluate the controllers varied by no more than 10% among beds, and the air temperature throughout the greenhouse varied by less than 1°C. The water used had a pH of 7.2, a conductivity of 0.2 milliseimens, and was free of suspended organic matter.

The mist control units tested were:

1. **Cyclic Timer.** This had 3 timing units:

(a) 24 hour clock

(b) time off (0-60 min)

(c) time on (0-30 sec)

The misting rate was controlled by varying the time cycle manually. The 24-hour clock was set to turn the unit on and off at sunrise and sunset, respectively.

2. **Paper Sensor** (Jeffrey Electronic Control)

This unit functions by maintaining a paper strip at a pre-set electrical conductance which depends on moisture content, salt content, and temperature. To prevent an excessive accumulation of salts by evaporation the paper was changed weekly. Past experience has shown this to be essential for the reliable operation of this type of unit. When the conductivity of the paper falls below a pre-set value the unit turns on the mist until the pre-set point is reached again (with some hysteresis). Misting rate was controlled by varying the pre-set valve.

3. **Light Sensor** ("Weather Watcher-D" — Jeffrey Electronic control)

The amount of light in the greenhouse is measured by this unit and when a pre-set quantity has been received it activates the mist for a predetermined time. Mist rate is controlled by internal shading of the sensor.

4. **Resin Block** (Modern Networks — 6001)

This unit estimates misting requirements by measuring the capacitance caused by the water film on a resin block. When the capacitance (i.e. water film thickness) falls below a set point the unit activates the mist for a predetermined period. Control of the misting rate is achieved by varying the capacitance pre-set point. The time the mist is on is also set by the user (this determines the hysteresis of the unit). The sensor block was wiped with a cloth once a week to prevent a build-up of salts and dirt.

5. **Mist/Relative Humidity Controller** (Thermo-Mister — La Bella Vista Nurseries)

This unit maintains a preset temperature differential between a surface exposed to the mist ("dry" bulb temperature) and one kept continuously moist with a wick ("wet" bulb temperature). As the surface of the "dry" bulb dries out its temperature increases because it is no longer cooled by evaporation of water. When the "dry" bulb temperature exceeds the wet bulb temperature by a preset amount the mist unit is activated until the differential is reduced to or below the preset value. Misting rate is controlled by varying the temperature differential.

Criteria used for evaluation were:

1. **Ability to maintain a moisture film**

This was assessed by visual observations of test plants with a range of leaf types (*Pilea*, *Callistemon* and *Dieffenbachia*) and continuous electronic recording with thermocouples attached to paper strips placed in each of the misting beds. A saturated paper strip was maintained as a wet bulb reference. Drying of the paper strips could be detected by deviation from the wet bulb reference towards the ambient temperature.

2. **Water usage.**

This was measured by placing 100 mm diameter containers on the mist beds (2 on each).

3. **Rooting of test plants.**

Cuttings of *Pilea cadierei*, *Callistemon viminalis* 'Hannah Ray' and *Dieffenbachia* 'Compacta' were placed on each of the mist beds to determine the effect of the control units on the rooting of a range of plants. Three replicates of 20 cuttings of each plant was used. Assessment was by total number of cuttings rooted and a grading score of root formation.

For 1 week prior to the commencement of the trial control units were adjusted to provide a continuous film of water with minimum water usage over a variety of environmental condi-

tions. Controls were also adjusted as required during the course of the experiment.

After the initial 6 weeks trial the light sensor and mist/ relative humidity controller were assessed for an additional 5 months during routine propagation by cutting in the greenhouse.

RESULTS AND DISCUSSION

Performance of the mist control units was generally in accordance with theoretical considerations. When all the units were properly adjusted and maintained during the initial trial of 6 weeks they all provided a constant moisture film over the test plants. There was also no significant ($P > 0.05$) difference in either number of cuttings rooted or root formation among beds controlled by the various units.

The most obvious difference among the units was the level of maintenance and readjusting of settings required. After the initial calibration the light sensor and Thermo-Mister required no further attention. Unlike the manufacturer's recommendations the Thermo-Mister did not require cleaning or filling although this may well be necessary if poor quality water is used.

The settings of the paper sensor and resin block units required small adjustments between their weekly maintenance despite the fact that good quality water (i.e. low in salts) was used in this trial. The resin block required wiping weekly. Both tended to drift slightly in their settings between cleaning or replacement due to a build up of salts. The settings on the cyclic timer required frequent attention (1 or 2 times daily) due to changing weather conditions and because it had to be adjusted to the maximum expected rate of evapo-transpiration in any time period. It used 25% more water than any other unit. There was little difference in water usage among the remaining units.

During the 5 months after the completion of the initial 6 weeks trial the Thermo-Mister and the light sensor maintained a film of water on the cutting leaves during routine propagation except on a number of days with maximum air temperatures of over about 38°C. On these days cuttings in the mist beds tended to have leaf surfaces drier than normal — although they apparently suffered no ill effects. A worthwhile improvement to these two units may be to slightly increase the misting rate at higher air temperatures.

MECHANICAL AIDS TO PLANT PROPAGATION

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Recently I have heard prominent Australian nursery operators remark that plant propagation is labour intensive and mechanisation of propagation is not possible. Such a point of view misrepresents the role that mechanisation can play in the propagation of plants and demonstrates a misunderstanding of the role of the plant propagator.

Much of the routine work of plant propagation is repetitive and predictable and can be carried out by relatively unskilled nursery personnel. Many of the routine operations involved in plant propagation can be performed easily by mechanical aids. The role of the plant propagator is becoming increasingly advisory and supervisory in the selection of propagation techniques, appropriate materials, facilities and equipment.

The objective of mechanisation is to increase the efficiency of the operation by improving the efficiency of staff and by making their job easier (3). Rarely does the introduction of machinery eliminate manpower; the integration of man and machine achieves the best results (3). A study to demonstrate the most efficient method of operation of a potting machine established that maximum output was achieved with a labour force of seven (2).

In order to understand the role which mechanisation can play it is necessary to examine the complete production system. A nursery production system is a sequential series of operations which lead to the production of a finished plant product (1). Most complete production systems consist of four distinct stages:

(i) Propagation stage

(ii) Transplant or tube stage

(iii) Growing-on stage

(iv) Marketing stage

A detailed analysis of the operations involved in each stage and the sequence in which they are carried out can identify repetition and pinpoint areas where efficiency of production can be improved. A very comprehensive review of the development of a systems approach to nursery production has been produced by Verma (3) in which systems analysis using a computer simulation model is advocated.

It may not be practical in a small nursery situation to go that far in operational analysis but the preparation of a simple operational flow chart will enable each stage in the overall system to be examined separately to determine where improvements can be made (1).

Table 1. Operational Flow Chart — Propagation by Seed (1).

Propagation Stage
Mixing of propagation media
Transport of media to steriliser
Sterilising/pasteurising of media
Filling of propagation containers
Bulk sowing of seeds
Covering of seeds
Transport to propagation facility

The sequence of operations outlined in Table 1 illustrates that in the propagation of plants by seed all of the operations can be accomplished with mechanical assistance.

Media Mixing. A wide range of media mixing equipment is available to suit the volume requirements of most nurseries. Two basic principles of ingredient mixing are used:

(1) Agitation of ingredients in a rotating drum, a system based on the equipment used in concrete mixing.

(2) Paddle or ribbon mixing in a static chamber, as used in the mixing of stock feeds.

Transport of Media to Steriliser. The discharge of mixed media from the mixer and its transport to the steriliser (or directly to the container filling area if sterilising is not done) can be accomplished with the use of mobile trolleys or belt conveyors. It is desirable to eliminate any unnecessary handling of mixed media and a number of innovations can help to achieve this; e.g. it is possible to use many rotary mixers as a pasteurisation chamber, or to utilize the transport trolley as the pasteurisation chamber.

The use of belt conveyors is becoming increasingly common in nurseries for the transport of media to the work areas and their use can contribute greatly to improvements in efficiency.

Filling of Propagation Containers. The filling of propagation trays or community pots can be quite simply carried out using belt conveyors and overhead hoppers. More sophisticated equipment involves the incorporation of devices which meter media quantities to discharge precise amounts into each container, vibrate the filled containers to settle the medium and level the surface uniformly. Attachments can be obtained for many potting machines to enable tray filling to be carried out efficiently.

Bulk Sowing of Seeds. A wide range of mechanised seed sowing equipment is available to enable more accurate placement of seeds during the sowing process. Not only is the efficiency of seed sowing improved but the transplanting stage of seedling production may be eliminated resulting in a significant cost saving.

Vacuum seeding equipment is the most widely used method of mechanical seed sowing but pneumatic equipment, although much more expensive, is becoming more common in Australian nurseries. Small seeds or seeds of an irregular shape can be pelleted to improve the efficiency of mechanical sowing. The techniques of pre-germination of seeds prior to sowing allow greater uniformity of production and provide the nurseryman with more accurate control of quality.

Covering of Seeds. Hoppers and belt conveyors can also be used very successfully for placing a layer of covering material on top of sown seeds. The incorporation of photocells and vibrator plates enable the covering to be applied quickly and evenly with no spillage or waste.

Transport of Propagation Containers. A wide range of manual and mechanised trolleys are used for the movement of plants within the nursery with a high level of efficiency. However, even the best trolleys still require a considerable labour input in loading and unloading.

Palletisation of plant material at the propagation stage and for growing-on of plants substantially reduces the labour inputs of loading and unloading. Redesign of pallet handling equipment is necessary in order to improve the utilisation of nursery growing space.

The use of mobile or travelling benches will provide an even higher level of efficiency in the movement of plants within the nursery. The containers are placed directly onto the travelling benches at the propagation stage and thereafter no manual handling of individual containers is necessary. The travelling bench allows a moving production line concept to be introduced to the nursery. Newly propagated plants enter through one end of the production facility and emerge through the other end when ready for sale.

Travelling benches can also facilitate conditioning or hardening off of plants within the nursery without the need for manual movement of individual plants. This is particularly valuable in the production of seedling crops such as vegetables which are destined for field planting. The benches filled with

plants are wheeled or rolled outside during the daytime to be hardened off in full sun but they can be easily and quickly returned to the protected growing environment in the event of unfavourable weather conditions.

SUMMARY

The examples of mechanisation used in this paper relate primarily to aids used in the sequence of production operations involved in the large scale production of plants by seed. An analysis of the production systems used in the propagation of plants by cuttings or other vegetative propagation techniques would reveal similar opportunities for the use of mechanical aids.

The decision to incorporate mechanical equipment in the nursery must take into account the scale of operations of the nursery. Large scale output of a limited range of plants lends itself better to mechanisation than the small nursery with wide diversity of production.

As cost pressures continue to increase manpower productivity becomes of increasing importance to the nursery operator and the incorporation of mechanical aids will do much to increase that productivity.

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HORTICULTURAL EDUCATION IN THE NORTHERN TERRITORY

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Abstract. There is a lack of horticultural training in tropical Australia. The Darwin Community College commenced apprenticeship training in 1980 and a certificate course in tropical horticulture in 1983. The future of horticulture, particuarly in the areas of field cropping and nursery production, appears good and these courses are providing trained personnel for this developing industry.

INTRODUCTION

The horticultural industry in the Northern Territory (N.T.) is destined for a bright future. The regreening and population growth of Darwin since the devastation of cyclone Tracy in 1974 has resulted in a solid nursery sector being established and nurseries are now located in most of the major centres of the N.T.

Since the granting of self-government in 1978, with the assistance of the N.T. Department of Primary Production, C.S.I.R.O., and N.T. Agricultural Development and Marketing Authority, the fruit and vegetable production sector has also been finding its feet. The landscaping, cut flower, parks and recreation sectors are also horticultural growth areas.

In all aspects of horticulture in the N.T. there is a need for suitably trained staff. Darwin nurserymen recognized this need in the late 1970's and through the Northern Territory Nurserymen's Association made representations for the establishment of a local horticultural course at a trade level.

DARWIN COMMUNITY COLLEGE

After several years of being involved in a succession of rather limited short courses, in 1982 Darwin Community College commenced the first formal Horticulture Apprenticeship Trade Course.

The Horticulture Section of the Darwin Community College School of Trades is now responsible for all formal horticultural education in the N.T. No courses are at present available in other centres although it is anticipated that training may become available in Alice Springs at the Community College of Central Australia and in the Katherine District at the Katherine Rural Education College at a future date.

The Community College of Central Australia conducted the South Australian part-time Certificate of Amenity Horti-

culture for three years to the end of 1981 but is at present not involved.

Currently, Darwin Community College is involved in horticultural education at three levels — an apprenticeship award course, certificate award course, and other non-award courses.

HORTICULTURE APPRENTICESHIP TRADE COURSE

In contrast to the larger southern states, there is only one declared trade of horticulture in the Northern Territory. The apprenticeship training period runs for a duration of four years and the three year Horticulture Apprenticeship Trade Course may be undertaken anywhere within that period. Any person over the age of 15 may be apprenticed.

After looking at the models then available from other Australian states, the trade course advisory committee in 1979 selected the Victorian horticultural course guidelines, subject to various modifications appropriate to N.T. practices and environmental conditions being carried out by the first appointed lecturer in horticulture.

Because the number of horticultural apprentices in the N.T. at present does not justify separate nursery, fruit, vegetable, and other specialist streams, the course is of necessity a general one. However, students are given the opportunity in their assignments, projects, etc. of concentrating upon their own specialist area and, where numbers permit, will be grouped together according to similar employment areas.

Due to the long distances between population centres of the N.T., the course is conducted wholly on a block-release basis, at present 4 two-week blocks per year.

Each of the three stages contains 10 subjects, with the first stage of the course providing an introduction to the basic principles and skills involved in Territory horticulture. The other two stages are intended to provide added skills at a more advanced level with a gradual concentration on certain areas such as nursery container production, for example.

Because of the growth of the industry and the change in emphasis from a course initially providing for nursery apprentice training to one catering for fruit and vegetable and parks and recreation apprentices, the present curriculum is in dire need of review.

It is intended that any major changes to the N.T. Horticulture Apprenticeship Trade Course curriculum in the near future will be made in conjunction wtih current moves to implement an Australia-wide horticultural trade course "core curriculum".

Apart from the continuing lack of funds and staff, the main problem facing the apprenticeship course is the large geographical area from which its students are drawn. The environmental changes over the 1000 kilometre gap between Darwin and Alice Springs necessitates a separate plant identification list for students from each end. The arid climate of the Centre, with its hot summers and cold winter nights, allows the culture of a different, more temperate, range of plants to those grown in the tropical Top End, where the high day and night temperatures are reasonably constant, particularly during the humid wet season.

Most of the exotic plants now in cultivation in Central Australia are well-documented in regard to propagation methods, cultivation and so on, whilst in the the Top End there is a scarcity of information about many plants, especially exotic ornamentals and southeast Asian fruit and vegetable species. Lack of information about N.T. native ornamentals, particularly in regard to salt tolerance and so on, is common to both ends.

Compared to horticultural institutions in southern Australia, we also suffer from a general lack of printed, film, and audiovisual teaching aids, dealing with tropical conditions. However, this current lack of information concerning ornamental and edible horticultural crops, on the other hand, presents an exciting prospect for research and experimentation in education.

This brings me to the second level, that of the technician certificate.

CERTIFICATE OF TROPICAL HORTICULTURE

Since 1976 a need for a technician-level horticulture course has also been identified and, due to constant enquiries from prospective students and pressure from people in the industry, Darwin Community College was given ministerial approval to commence the course in 1983.

The course provides training over three years, part-time for people already employed in, or those intending to work in, the horticultural industry in tropical Australia, more particularly the Top End of the Northern Territory.

At present, most trained personnel have gained their qualification in southern areas or overseas with temperate crops and climates and face a period of adjustment and learning before they are working here at full potential.

Although the principles of horticulture are the same worldwide, its practice in an area such as the tropical Top End

requires a slightly different knowledge and approach. Thus the term "tropical" has been used to indicate that students successfully completing this "Certificate of Tropical Horticulture" are familiar with and have had experience in the production and cultivation of horticultural plants in a tropical monsoon environment.

The course is based on the long-established "Horticulture Certificate (Part-Time)" course conducted at Ryde School of Horticulture, New South Wales, which was also the model for similar T.A.F.E. "Certificate of Horticulture" courses now conducted thorughout temperate Australia.

As shown in Table 1 the present course structure consists of four units per stage with additional excursions and assignments bringing the total course time to 1020 hours.

Table 1. Course structure for the Darwin Community College Certificate of Tropical Horticulture.

Stage 1 (8 hrs/wk × 36 wks)		
Horticultural Botany 1		
Tropical Soil Science		
Propagation 1.		
Tropical Horticultural Studies 1.		
Stage 2. (8 hrs/wk × 36 wks)		
Horticultural Botany 2.		
Tropical Plant Protection		
Propagation 2.		
Tropical Horticultural Studies 2.		
Stage 3. (8 hrs/wk × 36 wks)		
Compulsory Units	-	Business Management (Hort)
		Horticultural Irrigation
Option 1	-	Nursery Practice
		Tropical Nursery Crops
Option 2.	-	Post-Harvest Handling and Marketing
		Tropical Horticultural Crops
Option 3.	-	Turf Management
		Tropical Landscape Design & Construction.

OTHER NON-AWARD COURSES

Darwin Community College is also involved in conducting recreational courses for the general community in areas such as home fruit and vegetable growing, plant propagation, and landscaping. The college is also open to approaches from the industry to conduct specialist short courses, seminars, and the like.

The last area in which horticultural training will be provided is in the international sphere. Because Darwin is so close to southeast Asis and links between the Northern Territory and countries such as Brunei, Malaysia, and Indonesia are

increasing, it is intended that short-duration courses will be provided in aspects such as nursery container production, propagation techniques, and so on.

THE FUTURE

Since 1980, horticultural education in the Northern Territory has been placed on a firm footing and, with the basic courses now established, a steady supply of staff trained in various aspects of tropical and arid-zone horticulture should be available to keep the industry growing.

Whether providing horticultural education in our colleges or by distance education through the means of correspondence, adequate funding must be provided. This means that the industry must make its needs clear and present a good case to our government. Perhaps by the 1900's we might be offered a seat in the University of the Northern Territory.

HOW COMPUTERISED RECORD KEEPING CAN HELP THE PROPAGATOR

PENELOPE A. ROSE

Tubegrowers,
Namba Road, Duffy's Forest, Sydney

Why the propagator needs records. The nursery industry in Australia has grown from being a small cottage industry in which the owner-operator "knew it all" from years of on-the-job experience, or simply "green thumb", to one which is literally a branch of agricultural science. As no scientist can exist without records so, in 1983, should no horticulturist.

The propagator needs records not just to prove a technique does or does not work but to compare techniques. In a time when making a profit is essential for survival it is enormously important to know exactly which plants are being produced economically, which techniques give the best results, and which operators are the most efficient.

What records are needed. The records needed are determined by the type of information required. Before collecting information, it is essential to ensure that it will be used.

Consider some of the questions which may be asked of the propagator and for which he may have to search out data in order to provide the answers:

1. How long does it take *Plant A* to reach a saleable size? Is this an optimum time? Does it vary with the seasons? Does

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Consider some of the questions which may be asked of the propagator and for which he may have to search out data in order to provide the answers:

1. How long does it take *Plant A* to reach a saleable size? Is this an optimum time? Does it vary with the seasons? Does

it vary with the operator? Does it vary with the source of the material?

2. What percentage of the cuttings taken reached a saleable size? Is this always the same? At what stages during the production cycle were the losses encountered? Were they due to unusual circumstances?

3. Is the production of *Plant B* economic. Is it time consuming at any stage? How long did it stay in each stage?

4. When were cuttings taken of *Plant C*? Could they have been taken earlier or later and been ready at a more suitable time?

5. What seed should be ordered next month in order that plants scheduled, say for spring, can be sown?

6. If you run a series of experiments on propagation of *Plant D*, can you provide parallel results for comparison during the normal course of record keeping?

What information should be collected. The information on plant production can be collected at each stage. Basically it will be as follows:

PLANT NAME — Batch Number

The batch number will be a specific number related to the date during which the group of plantlets (cuttings or seeds or culture) starts life. A normal system would include YEAR-MONTH-NEXT NUMBER, thus 83-05-001, 83-05-002 for groups of plants started in May, 1983.

NUMBER OF PLANTS

In the case of cuttings, where these are set individually or into community trays with standard spacing, these can be estimated fairly exactly. For seeds — with large seeds this may be accurate but with small seeds this will have to be an estimate. Where an estimate is used it may be useful to weigh the seed and record it.

SOURCE OF MATERIAL

Where seed is bought in, the supplier should be noted. Where stock is taken from plants on ground, mother plants, or general nursery plant beds, this too is important information.

LOCATION IN GLASSHOUSE

The location in which cuttings or seeds are placed should be noted with date they were put in.

OTHER INFORMATION

Other information which may be collected at the time the plant "starts life" includes the following:

Contract # — where plants form part of a forward order contract

Operator — the group or special operator performing the task

Hours — the time in hours or minutes as apppropriate for task to be performed.

General information — this might include number of trays used, type of hormone, mix for cuttings, special treatment, formula code for tissue culture medium, and a host of other specific information for the batch which may indicate reasons for success or failure.

Manual or computerised record storage. There are a number of reasons why computerised record keeping is far superior to manual records. The most important is the time saving involved. There can be no doubt if genuine reports are required on a number of different plant species grown by any nursery then computerised record keeping is the ultimate. The ultimate, provided the computer has been programmed to receive the type of data to be collected and to report meaningfully on it.

The advantages of computer record keeping come in two ways:

(a) The time taken to enter data through a keyboard as compared to sorting through cards (as in a manual system) and hand writing the information is minimal.

(b) The computer is able to perform sorts, comparisons, and match required information in a tiny fraction of the time which would be needed by a clerk. Thus, information is available from a computer exactly when it is needed and up to the minute correct.

In addition to this, computerised record keeping ensures that the propagator is kept working in the area in which he is skilled, growing plants, the clerk is kept working in the area in which she is skilled, typing on the keyboard, and generating reports for the propagator.

What sort of reports can be obtained. Depending, of course, upon the software and on the options that are available to the user of the computer, reports CAN be obtained for any information that the propagator can think up. Once the data is entered to the computer, reports may be generated to give:

— Comparisons of batches of the same plant

— History of the batch of a particular plant from the time it is started to the time of last sale.

— Reports on the plants available at a particular age, particular container size, for a particular contract . . .

— Plants ready to be planted out.

— Plants ready to be sown as seeds in a particular month.

What size computer. Many computer companies promise many things. By the time you find out they aren't quite what you thought it is too late.

A good rule of thumb is that to integrate and control all the functions of a plant production nursery, a minimum of 15 megabytes of disc storage (Winchester or fixed disc preferably), a 16 bit processor, suitable backup medium, one visual display unit, and a printer is needed. In May 1983, this would have cost about 25,000 Australian dollars. However, in a very short time additional visual display units and a second printer would be required. To install something smaller simply means that less information can be stored and retrieved with less speed. Although time is ensuring you receive more for your money, the money you spend is not going down because the labour involved in putting the systems together is increasing. Software, or the programmes which make the computer think and work, are still the most expensive part and least efficient area of computerisation.

MACADAMIA HUSKS AS A POTTING MEDIUM FOR ORNAMENTALS

TIM TROCHOULIAS

Tropical Fruit Research Station, Alstonville, New South Wales

ANDREW J. BURTON

"Betta Plants", Booyong, New South Wales

Abstract. Ten ornamental species were grown in two combinations of sand and macadamia husks (1:1, 1:3) and compared to a control which included sand, peat, sawdust, and polystyrene beads (1:2:2:3). After 51 days all species growing in both the sand and husks media showed significantly ($P<0.05$) greater vigour than the control. The fresh and dry weight determinations of the tops of one species examined (Nephrolepis exaltata) showed significantly ($P<0.05$) higher growth rates than the control. Macadamia husks are suitable for use in potting media with a wide range of ornamentals.

INTRODUCTION

Macadamia husks, the fibrous carpels which enclose the nut and are mechanically removed after harvest have been shown to be an inexpensive alternative to peat as a component

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INTRODUCTION

Macadamia husks, the fibrous carpels which enclose the nut and are mechanically removed after harvest have been shown to be an inexpensive alternative to peat as a component

of potting media for raising macadamia seedlings in the nursery (2). Husks can be used after composting in a heap for 6 to 9 months or after 4 to 6 weks if hammermilled. An experiment was initiated at Booyong, New South Wales (29°S) in December, 1982, to investigate the response of 10 ornamental species to potting media containing husks.

MATERIALS AND METHODS

The following 10 species were used:-

1. *Oxalis hedysaroides 'Rubra'*
2. *Epipremnum aureum* [Syn. *Scindapsus aureus*]
3. *Nephrolepis exaltata*
4. *Cissus discolor*
5. *Monstera deliciosa*
6. *Syngonium podophyllum*
7. *Chamaedorea elegans*
8. *Begonia* 'Orange Rubra'
9. *Aphelandra squarrosa* 'Dania'
10. *Pepermomia obtusifolia*

Plants were struck in 50 mm rock-wool cubes; 15 plants of each species were selected for uniformity.

Three potting media were examined:

a) sand and husks (1:1)

b) sand and husks (1:3)

c) sand, peat, composted sawdust, a. expanded polystyrene beads (1:2:2:3) as the control.

The husks were hammermilled to 5 mm size and composted for six weeks.

The 1:3 sand-husk mix was used to reduce the weight of the growing medium. All three media had the following fertilizers added per cubic metre:

2500 h 8 to 9 month Osmocote (NPK 18-2.6-10)

750 g dolomite lime

1000 g Micromax (trace elements)

50 g ferric sulfate

10 g flowers of sulfur

The plants were potted into 140 mm squat white pots and replicated into five blocks at random. Occasionally plants were removed from their pots to gain a visual impression of water holding capacity. After 51 days the plant were scored for vigour, according to the following scale:

1. very weak, 2. weak, 3. moderate, 4. strong, 5. very vigorous

All plants (15) from one species *(Nephrolepis exaltata)* were removed from their pots, composite soil samples taken from the three treatments, and the potting medium washed from their roots. Fresh and dry weight of tops and roots were then determined.

RESULTS AND DISCUSSION

The two media incorporating husks produced significantly ($P<0.05$) more vigorous plants than the control (Table 1).

Table 1. Effect of potting medium on top growth of ten species (1 = very weak; 5 = very vigorous).

Treatment	Score
1. Control	3.520
2. Sand/husks (1:1)	4.053
3. Sand/husks (1:3)	4.020
LSD .05	0.297

Fresh and dry weight of *Nephrolepis exaltata* tops produced significantly ($P<0.05$) greater growth than the control (Table 2). This experiment has shown that a range of species, such as *Nephrolepis* and *Oxalis*, which are susceptible to reduced air porosity, through to *Begonia* and *Monstera* (Figure 1) which are relatively hardy, responded well to the use of husks in the potting medium.

Figure 1. *Begonia* 'Orange Rubra' 51 days after growing in (*left*) T-1 (control); (*center*) T-2 (1:1 sand/husks); and (*right*) T-3 (1:3 sand/husks).

Removal of the plants from the pots before irrigation showed that the roots of plants in the control medium were dry and the foliage appeared stressed compared to the sand husks mixtures.

Table 2. Effect of potting medium on top weight of *Nephrolepis exaltata*

Treatment	Fresh wt. (g)	Dry wt. (g)
1. Control	13.5	1.86
2. Sand/husks (1:1)	16.3	4.20
3. Sand/husks (1:3)	22.2	3.92
LSD .05	9.45	1.65

The media incorporating husks had higher K and Mg at the end of the experiment compared to the control in *Nephrolepis* (Table 3). It can therefore be inferred that besides water retention properties, husks do have a better nutrient retention capacity for some elements or have a storage of nutrients within themselves as has been shown in previous experiments with husks (1). More work would have to be done to clarify the moisture and nutrient exchange properties of media incorporating husks.

Table 3. Chemical analysis of the potting media at the end of the experiment with *Nephrolepis exaltata*

	Treatment		
	Control	Sand/husks (1:1)	Sand/husks (1:3)
pH (water)	5.30	5.66	5.45
Conductivity (millimhos/cm)	0.43	0.48	0.78
Total N, %	0.20	0.18	0.36
K (meq./100 g)	1.23	2.85	6.15
Ca (meq./100 g)	18.54	11.24	18.25
Mg (meq./100 g)	2.41	2.51	4.33
P (bicarb.)	52	62	69

Acknowledgements. We wish to thank Mr. I Musgrave for technical assistance, Mr. R. Darnell for the biometrical analysis, and Dr. D.R. Baigent for the chemical analyses. The staff of 'Betta Plants' assisted with the potting and maintenance of plants. Macadamia Plantations, Dunoon, supplied the macadamia husks.

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PROPAGATION OF *IPOMOEA HORSFALLIAE* IN HYDROPONICS

PATRICIA D. RAWARD

Delta Nurseries Pty. Ltd.
Coombabah, Queensland

Ipomoea horsfalliae is a native of the West Indies, a morning glory, commonly referred to here as cardinal creeper. Dense, glossy, palmately lobed leaves enhance the beauty of its clustered 6½ cm glossy, bell-shaped flowers, deep rose to cardinal red in colour; which bloom profusely from summer to mid-winter in southeast Queensland.

This showy creeper has been largely unavailable to the home gardener because its poor strike rate by conventional cutting propagation makes it non-viable as a commercial crop. With hydroculture as an alternative propagation method, the nurseryman can grow this beautiful plant economically and reap the benefits from a most desirable and rewarding crop.

The methods described in this paper are the results of trials carried out over a three year period. Many of the methods were duplicated in various standard propagation media; however, because of the extremely poor results in these media, the last year's work has been devoted entirely to hydroculture.

The Sub-Irrigation Gravel Unit. A commercial sub-irrigation system using 9 mm uniform gravel as a substrate in a V-shaped trough is used with an inlet-outlet pipe running the full length of the trough to ensure excellent drainage.

Large particles are used for maximum oxygen exchange during flooding which occurs automatically every 2½ hours during daylight but only twice at night.

Formula control is manual and a recirculating system is used to maintain economical use of nutrients and water.

Hygiene of Unit. Important points to watch are, firstly, that the gravel is thoroughly washed so no dust or limestone is left in it. The pipes from the media tank, the troughs, and the gravel should be sterilized with 1/100 formalin. After 24 hours rinse unit thoroughly.

Provided the unit is kept clean it may be used continuously for at least 5 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 use 5 ppm Benlate as a preventative treatment in damp, overcast conditions.

The hydroponic unit that we use is situated in the propagation house with forced air ventilation, temperature range 21 to 26°C, humidity 70%, and good light (1200 foot candles). 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° and the air temperature does not vary more than 5° and the air temperature does not fall below 12°, or exceed a range of 20°C daily, all cuttings, although slower to strike, will perform well.

Formula:

	M/F	M/W	Quantities
(a) Monopotassium phosphate	KH_2PO_4	(136) =	0.4536 kg
(b) Potassium nitrate	KNO_3	(101) =	2.2680 kg
(c) Calcium nitrate	$Ca(NO_3)4H_2O$	(236) =	3.5380 kg
(d) Magnesium sulfate	$MgSO_4 7H_2O$	(246) =	1.4152 kg

Water to 3785 liters

Ppm of the elements given in the above formula: N 190; P 34; K 275; Ca 52; Mg 45

Other trace elements should be adjusted in relation to the water used.

Scale for trace elements:

	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
Molydbenum (Mo)	0.01	0.1	0.04

Notes:

1. Formula is used half strength for propagation purposes.
2. Trace elements are so minute that they are best calculated after obtaining a water analysis.
3. Accuracy is vital, a few grams either way will not do!
4. Careful storage and use of pure chemicals is of utmost importance if mixing your own formula.
5. Use clean filtered water.
6. pH of water should be adjsuted to 7 before adding nutrients. Use phosphoric acid or dehydrated lime.
7. Calcium nitrate is added separately.
8. A stock solution of trace elements is preferable, but iron should be added alone.
9. Check pH and conductivity after mixing formula.
10. Check all electrical and automatic systems for reliability and correct settings.

11. Prepare propagation material in clean aseptic conditions.

12. Plant out cuttings.

13. Commence irrigations.

Maintenance.

Daily:-

1. Cleanliness, remove damaged plant material, spilled soil, etc.; if gravel is soiled, remove, clean, and replace.

2. Function test.

3. Check time clocks and adjust if necessary.

4. Top up nutrient solution with water.

Weekly:-

1. Flood troughs to overflow and sprinkle cuttings. This removes any excess salts from top 2½ cm and prevents build up of dust.

2. pH (5.8 to 6.8) and conductivity (1.0 to 1.2) should remain steady or fall progressively.

Simple formula adjustments:

1. 28.3 gm iron sulfate weekly.

2. After 3 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 10% phosphorus boost may be necessary.

4. If pH and conductivity is swinging or rising rapidly a new solution needs to be prepared.

5. Half strength 3785 litre solution lasts 6 to 8 weeks if correctly managed.

6. Benlate, 5 ppm in solution, is used in winter.

7. Do not increase irrigation times, even on very hot days. New cuttings may be misted if humidity is low, every 6 hrs. for 48 hrs.

8. When using sprays, fungicides, etc., check for trace element content before use in hydroponic.

9. Remember there is no normal soil buffering effect in a hydroponic solution, so whatever is put in will be taken up by the plants.

Propagating *Ipomoea horsfalliae:*

Stock plants should be healthy, free from disease and insect infestation, true-to-type and vigorous. Take cuttings in spring (late October) when new growth is most vigorous and shortly before the new season's flower bracts are formed. Then

there is time for a second pruning in December without losing the beauty of the summer and autumn blooms.

Double node cuttings 30 to 35 mm long are taken from the last 1½ m of the previous season's growth or from new growth, not younger than 2 months. Variable, but mostly poor results are obtained with other wood.

To prevent damage to cuttings when planting into gravel use a stick with a central groove and plant cuttings 6 cm apart. After 3 to 5 weeks callused and rooted cuttings will be producing new trailers and can be planted out. Between 95 and 100% strike is obtained with the recommended wood (Table 1).

Table 1. Effect of cutting wood type on hydroculture propagation of *Ipomea horsfalliae*.

Time	Age of Wood	Number of cuttings Started	Rooted	Planted out
October, 1982	Old wood; last year's growth	96	94	94
October, 1982	New growth (2 months)	104	104	104
October, 1982	Hardwood (No leaf)	48	2	2
October, 1982	Tips and other	56	20	18
December, 1982	New growth (2 months)	56	53	53

Plantlets are carefully removed from the gravel using a grooved stick and and then potted into a good open mix, such as pine bark and sand, and then staked. They are kept in the glasshouse for 5 days to avoid shock and then shifted to 50% shade. Root growth is rapid during the first weeks and plant growth is normal.

USE OF HERBICIDES IN TUBE-STOCK PRODUCTION

ADRIAN BOWDEN
Adrian's Nursery
Thomas Street
Jandakot, Western Australia 6164

There are a number of points that should be checked before using any herbicide on your tube stock.

1. Read any available literature on the herbicide, noting such things as frequency of application.

2. Pay particular attention to the climatic factors in the data.

3. Pay particular attention to the soil mix being used in obtaining the data.

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3. Pay particular attention to the soil mix being used in obtaining the data.

4. Frequency of irrigation needs to be noted also.

5. Having done all that, see if the literature deals with any of the plants you are growing.

6. Before embarking on large scale treatments do small trials with all plants and sizes then assess the results.

Weed control in a wide range of tube stock can be accomplished if raised benches are used, with windbreaks around holding areas, and with the headland and underbench areas sprayed with Tryquat or Roundup.

Tryquat is non-residual, very toxic to the operator, but very effective on any germinated weed seedlings, causing death within 48 hours except to such weeds as couch, paspalum, and *Cyperus* which will regrow. Roundup can be used on those not killed by Tryquat but up to 3 weeks are required to achieve a kill. In our climate we use a wetting agent and some dissolved urea in the tank to make the Roundup more effective. If used according to the manufacturer's directions a most unsatisfactory kill is generally obtained under our conditions.

It is important to use clean soil, clean containers, and clean water, i.e. free from weed seeds.

Regulating the amount of water and liquid fertilizer applied discourages the growth of liverwort and/or mosses. The time that tubes are held before repotting should be minimised.

Using such an approach gives tubes with none or very few weeds. We keep them that way by spraying with Yield and/or Tenoran. Both these products have advantages and disadvantages. Yield is applied as a spray every 3 months over any plants that do not have a set growing period. Do not spray on anything that is deciduous or semi-deciduous or bulbous or on evergreens such as *Hardenbergia*, *Lantana*, *Cyathea*, *Abelia*, *Rosa* or *Tamarix*. It is recommended on eucalypts, *Grevillea*, *Callistemon*, *Boronia*, *Banksia*, and assorted palms.

Yield can be used as a growth retardent on such plants as willows, roses, weigelas, hydrangeas, and flowering quince. It generally does not kill plants but just retards growth for up to 6 months when they again commence normal growth. On our soil mixes we use 1 kg of 36% active ingredient per hectare or about 1,800 ml of 26% strength in a 200 litre tank. One needs to do his own calculations because of pressure variations in pumping equipment and different nozzle sizes.

On non-susceptible plants up to 3 kg per hectare can be used but this is unnecessary. All paths and below bench areas and plants are sprayed by a hand-held wand or boom spray. Watering in summer is at least twice a day and under these conditions weed control can be had for 12 weeks.

Any of the problem weeds commonly found in Western Australian nurseries, e.g. flick weeds, oxalis, milk weed, pampas grass, summer grass, crab grass, and thistles are being controlled by regular applications of Yield. Presently our soil mix consists of ⅓ silica + ⅔ sawdust-woodwaste (all hardwood). Any weeds that we happen to miss can be sprayed with Tenoran, particularly flick weed, even up to the seedling stage. Care needs to be taken not to spray Tenoran on groundcovers, asparagus ferns, or grevillias.

Yield can be applied all year round but we do not spray in temperatures over 30°C and the automatic water follows along when scheduled. Tenoran, on the other hand, is allowed to dry on the weeds and plants overnight for best results.

We have conducted trials with Goal, Dacthal, Devrinol, Casoran, Ronstar liquid, and Simazine and are presently doing some trials with Ronstar granuals which look very promising.

PLANT PROPAGATION IN THE MIDDLE EAST

BEN SWANE

Swane's Nursery,
Galston Road, Dural, New South Wales

The growing of palms for food production is one of the most ancient forms of plant propagation. The arid countries of the Middle East such as Saudi Arabia and surrounding nations have propagated palms since time immemorial. The oasis and wadis surrounding sweet water wells and the areas under the palm plantations are used for other forms of plant propagation for many vegetables and fodder crops. Lucerne (alfalfa) is the main green crop grown for their animals.

Each palm tree forms an orchard square, approximately 8 metres by 8 metres, a small mound surrounds each square and holds the water for both palms and green crops. This water is drained off to the next square and the process of irrigation continues.

Over the last 10 to 15 years a great demand has developed for propagation resources which do not exist as we know them.

Seed production of eucalyptus, casuarina, and other Australian native plants is now well established. Other trees and shrubs are also produced from seed under these palm trees.

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Seed production of eucalyptus, casuarina, and other Australian native plants is now well established. Other trees and shrubs are also produced from seed under these palm trees.

Earthenware or terracotta pots are plunged about half their depth in the existing sand/soil mixture. The seeds are sown in these pots and receive their water by capillary movement. Water is also applied by spray from hoses over the tops of the pots. As soon as any sign of germination starts to take place this watering is stopped.

There are a few growers who sow seeds directly into prepared beds. The seed germination mixture is generally sand and European peat moss. This method using the existing soil + amendments is not very successful and the germination is often very poor.

The demand for cutting-grown plants has increased because many of the plants cannot be grown easily from seed. Vegetative propagation has created a demand for better propagation facilities and methods.

Generally speaking, plants like *Bougainvillea*, *Hibiscus*, *Clerodendron*, and *Tecoma* are propagated from semi-hardwood cuttings 18 cm in length and very solid material. No wounding or hormones are used. The cuttings are plunged into a well tilled soil/sand and peat mix under the palms and flooded in their normal irrigation cycle. Plants produced are often very unsatisfactory — root development often occurs on only one side of the plant. This may be due to the competition from the palm tree roots and the effects of the saline water.

Where cuttings are placed in terracotta pots and plunged into the sand, better results are obtained. However, at present much of the plant material is imported and grown-on from tube or liner size plants. This type of plant material is grown in Jordan, Syria, Pakistan, Lebanon, and India and is the usual type of cutting potted up in the nursery.

The growing-on of imported plants and the above cuttings have seen these nurseries expand under very harsh conditions. These conditions have resulted in this type of propagation. The water is so saline that mist propagation is just about out of the question. Nurserymen and propagators are reluctant to change their methods and they continue to use very old methods of propagation.

The collection of propagation material, even oleanders, is also a problem as both day and night temperatures are very high with low humidity. The material collected has to be very tough to survive under these conditions. Oleander is a native of Oman and is a beautiful plant in the wild. Animals graze among the oleanders with no apparent ill effects.

It is quite common to see air layers on all sorts of plants — oleanders, hibiscus, and bougainvillea just to name a few.

This method of propagation gives quite large plants under very harsh conditions and is very popular.

Nurseries could use mist propagation methods if the rain water was collected off roofs, etc.; however, this is very difficult as many areas such as the U.A.E. have not had more than 10 mm of rain each year for the last 15 years and in some places generations of people have never seen rain. Most underground water is very saline and not suitable for mist systems.

West Australia and much of the Northern Territory have plant material suitable for these countries. I recommend that plant propagators in the Middle East study Australian methods and plants in relation to salt tolerance, heat and drought resistance, and propagation.

Propagation of Australian dry land and salt tolerant plants has not been well developed as many of these plants are put in the "too hard" category. There are exceptions, however, and many of our plant propagators who persevere will be richly rewarded.

Plant propagators in Australia have vast quantities of native material available, (Table 1). However, selection of plants especially for dry lands and salt tolerance creates propagation problems. Evaluation of vegetatively propagated plants will take time as the selection for material suitable for reclamation of saline soils may involve field trials in many different situations. There is, however, a great opportunity for those propagators who do this form of research. Much of this has been done in Australia and our propagators should continue this work and increase the variety of plant material successfully propagated.

Table 1. Some native Australian genera suitable for dry land and salty environments.

Atriplex	*Hakea*	*Myoporum*
Callitris	*Hardenbergia*	*Olearia*
Callistemon	*Helichrysum*	*Persoonia*
Carpobrotus	*Helipterum*	*Petalostylis*
Clianthus	*Hibbertia*	*Petrophile*
Correa	*Isopogon*	*Ptilitus*
Dampiera	*Kennedia*	*Stylidium*
Darwinia	*Kunzea*	*Swansonia*
Dryandra	*Lachnostachys eriobotrya*	*Verticordia*
Eremophila	*Macropidia*	*Westringia*
Frankenia	*Melaleuca*	*Xylomelum*
Grevillea		
Acacia, *Banksia*, *Casuarina*, *Eucalyptus*	*selected seed lines and salt tolerant species*	

Millions of plants are required for regeneration programmes in mining sites and disaster areas both in Australia and overseas. The overseas requirements for Australian plants to suit the above conditions is larger than most plant propagators and nurserymen realize.

Much of Australia's nursery production, especially in West Australia, Northern Territory, and South Australia should be developed by our plant propagators and nurserymen for these Middle East markets. I can imagine how hard it would be for any plant propagator not used to saline waters, high temperatures, and desert conditions and shortage of propagation material to start a nursery.

There must be people in our society who have experience in this type of propagation and nursery production. The opportunity to grow plant material in Australia or in joint ventures in the Middle East and overseas countries exists for those propagators willing to accept this challenge. Examples of joint ventures can be seen in Saudi Arabia, U.A.E., Kuwait, and Bahrain. Indeed one Australian nurseryman is engaged in such a project in Kuwait.

Protected areas using natural windbreaks and buildings such as shade and glasshouses properly sited can and does soften the environment, enabling the use of more modern methods of propagation.

It is hoped that in the IPPS there will be plant propagators willing to extend their knowledge and expertise in the growing of salt tolerant dry land trees, shrubs, ground covers, and native grasses and present us with export opporutunities. In no way is any of this presentation meant to criticise the efforts and endeavors of plant propagators in the Middle East countries. Propagation of date palms is really wonderful and I admire the propagator's patience. Date production in the Middle East is of a high standard and has to be seen to be believed.

DEFLASKING AND CULTIVATION OF TISSUE-CULTURED PLANTS

ELIZABETH METCALFE

Tropicus Nursery
P.O. Box 505
Darwin, Northern Territory 5790

Darwin is situated in a tropical zone and experiences two seasons a year — a wet season in which we receive monsoonal rains with temperatures around 30 to 33°C and high humidity, and a dry season with low humidity and a greater diurnal temperature range, from about 18 to 30°C.

Environmental and climatic conditions are important factors to note and control when deflasking tissue cultures. The jars come from the air conditioned laboratory with a constant temperature of 26°C and a high humidity.

To prevent desiccation during deflasking the plants are handled quickly and are placed in a humid tent as soon as possible. A fungicide, such as Zineb, is used as a soil drench and also as a plant wash. This is a preventive procedure that guards against fungal attack. The use of University of California mixes also helps prevent soil-borne fungi attacking the tender growth. The most commonly used U.C. mix is of 75% peat, 25% sand and a small amount of slow-release micronutrient.

All deflasking takes place in the propagation or mist house. The sealed, sterile jars contain masses of tiny plants growing on an agar medium. The agar and plants are tipped out and small clumps of plants are separated and washed in a fungicide solution to remove all traces of agar. Then they are inserted into trays of U.C. mix drenched with fungicide. It is best to minimize shock by leaving them in clumps and insert them carefully into the medium rather than burying them. Hands must be washed well and forceps are used to handle plants gently.

Trays of deflasked plants are put under a clear plastic tent on the propagation bench with no automatic misting as this gets them wet and then there are problems with fungal and bacterial attack. Humidity is maintained with a fine mist from a hand mister. Both temperature and humidity are constantly checked by the operator.

When the plants are well established and growing they are removed from the tent and hardened off under normal mist. The plant clumps are then divided into separate plants and potted into tubes and grown under mist with regular applications of liquid fertilizer. They are finally potted-on and established, ready for sale.

FIXING CLIMBERS TO STAKES WITH ADHESIVE LABELS

ROGER PEATE

26 Kardinia Crescent,
Warranwood, Victoria 3134

In early autumn, 1982, various adhesive labels were tested to determine if they could be used to fix climbers to bamboo stakes. We had to stake many thousands of climbing plants with very soft stems. Twist ties tightened sufficiently to hold the plants up on the stake damaged the stems.

Quickstick International self-adhesive labels peeled off a backing sheet were used successfully. These are available from most news agents in a range of sizes. The most suitable size was 50 x 13 mm and these were available in sheets of 20 for about $3.20 per thousand. While we needed them to last for a week or two, by which time the plants would be self-supporting, the labels retained their effectiveness for many months.

There were no savings in either material or labour costs as compared to other staking methods. This was because staff had difficulty detaching labels from the backing sheet. This required two hands at a most inconvenient stage of the staking operation. If growers got together to order sufficient labels a manufacturer could produce them in a form that is easy to handle, possibly in rolls. Then I believe this system would have potential in the industry.

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HOW TO MEASURE AIR SPACE IN POTTING MEDIA

IAN TOLLEY

Tolley's Nurseries
Box 2, Renmark, South Australia 5341

A quick but effective method to determine the percentage of air space in a mix is as follows:

1. Get your test mix to average field capacity. If necessary add water to do this.

2. Use two 200 mm (8 in) pots. Put them together but separated by a thin plastic (0.002 in) film.

3. Fill the inner pot to normal height and density with the trial mix.

4. Add water by measure to the point where free water just shows above the mix (i.e. saturation point). A small depression in the mix will make it easier to determine when this point is reached.

5. Separate the two pots carefully and collect the drainage water in a bucket — this should take only 2 to 3 minutes until the pot is dripping slowly. The medium is then at field capacity.

6. Express the water added to the water drained as a percentage —

e.g. 2 litres (applied) = 100% of air space
1 litre (drained) = x
i.e. there would be 50% air space.

7. Parameters. For most plants, except ferns or water plants, the average mix should have not less than 25% to 35% air at the time of potting.

8. Use the same technique to monitor the loss of air space as the plant roots develop. If the air space gets down to less than 10%, it is likely that a more porous medim would be advantageous.

HOW COULD BRITISH BOTANIC GARDENS HELP THE NURSERY STOCK INDUSTRY IN FINDING NEW PLANTS OF INTEREST?

TOM WOOD

Oakover Nurseries Ltd.
Potters Corner, Ashford, Kent

One may ask, "why ask the question" and I would state emphatically that there is most certainly a need. Plants of interest are capturing the imagination of many people, both within and outside the nursery stock industry and it is the duty of all concerned to fulfill this need.

Certain members have always known of the great potential and resources of the botanic gardens; however, thoughts were crystallized, appetites whetted and action motivated by the Southeast G.B.&I. Area on a one-day visit to Kew Gardens near London last summer. For many, much of the in-depth work being undertaken was seen at first hand for the first time. The role of the micropropagation unit and its potential as an aid to plant conservation on the one hand, and the rapid bulking of new introductions was just one aspect illustrating the potential of an informed botanical garden (one must admit that here avarice crept into the discussion and could have rapidly taken over). However, I contend that IPPS grower members should be looking at the broader implications and objectives of the nursery stock industry as a whole such as the responsibility of the Industry to preserve and enhance the environment, to conserve our natural flora, both nationally and on a world basis, and to provide a creative and active interest during leisure and recreation periods for the public that we serve. So what can the botanic gardens do — I suggest many things!

a) Plant collection. Expeditions of botanists in the field, looking in depth at particular Regions, Zones, or types of flora, have great opportunities.

b) Positive and accurate identification and naming of plants and the facilities for proving them.

c) The opportunity to display and demonstrate the usage of all plants, to educate and inspire the public to the use of new and unusual plants. (A million visitors pass through Kew Gardens each year).

d) Distribution. The control of introductions and distributions throughout the industry of proven, desirable and valuable material in co-ordination with the established nursery stock industry, thus ensuring the extended usage of a wider range of material, but first to return to:

The Question. The need for plants of interest exists, and the ability to maintain an interest in plants and plantsmanship is reaching a wider public. There is, happily, a new generation of young gardeners and, more importantly, young propagators in the nursery industry who are keen on their plants. Specialist nurseries are introducing plants from America, New Zealand, and Japan and a few from the wilds of China! These stalwarts should be encouraged, helped and promoted for there is much still tucked away in as yet unexplored areas and even little known gardens that are worthy of consideration in this context.

I am sure that all plantsmen dread to think of a situation where Garden Centre merchandising, on the basis of turnover per square metre per annum, dominates the nursery stock industry. If this attitude were allowed to take over, the country would be covered in Leyland cypress! Better to foster amongst our gardens the collecting habit and the possible one-up-manship of good garden plants and forms, such forms to be positively identified and recommended by a confident industry. The Long Ashton Clonal Selection Scheme set out to do just this, offering only proven plants; it provides an excellent basis on which to build a wider scheme.

Plant collections. Botanists and plantsmen who have knowledge, access, and, in many cases, the time and facility to undertake expeditions could collect for the nursery trade with their specific interests in mind — possibly with some sponsorship from individuals or the industry collectively. What is a new plant of interest? The ability to recognise potential for garden use as well as the necessity to complete collections of flora for the herbarium would be essential.

There is the possibility of the introduction of material to provide a base for breeding programmes. Either *in vitro* cultures or pollen could be used in the controlled environments that are available and frequently used in botanic gardens. Such a programme directed towards specific objectives could possibly produce a blue dahlia or rose, a black orchid or tulip, or any other commercially desirable objective. Whilst one would not advocate the production of garden monstrosities *ad nauseum*, with careful monitoring and control our enthusiastic plant collector could have his appetite fulfilled.

The naming, proving, and trialing of new plants. Nomenclature in the nursery stock industry is a grey area with many plants being traded under a wide range of names. A plea for simplification in the system, an acceptance of the correct, authentic botanical name together with a preferred common or commercial name, in addition, could avoid the existing dupli-

cation and confusion which beggars us all. The proving and trialing and identifying of the best forms of either bred or collected plants, with an evaluation on a commercial basis as well as garden merit, would have many advantages in the industry. Consultation between botanic gardens, the nursery stock industry, and other interested parties would be a basis for such proving and trialing.

Display and demonstrating plant usage. The setting up of demonstration gardens with regular meetings would help promote plants of interest together with recommendations for their usage. Organised parties and visitors from gardening societies and others particularly interested in plants could be accommodated at regular intervals. Topical demonstrations would become part of the normal day-to-day activity of a public relations staff with the possible participation of the media to give even wider coverage to new activity of interest to the millions of discerning gardeners waiting to soak up such information. Evaluation of appeal of plants could be undertaken in the form of a simple questionnaire, as is currently practised at the Park Floral, Orleans, France, where nurserymen regularly meet to analyse the opinions of the public on the plants they are producing and, as a result of this exchange, the introducer produces what the public wants. I have seen a further extension of this at U.B.C. where a vegetable and herb garden set out on the basis of ethnic groups of the population attracts visitors by appointment who are then told not only about the plants they are viewing, but also their usage within the kitchen. Such a system could be introduced here where plants and their usage in certain aspects of gardening could be dealt with from year to year.

Distribution. Having obtained your good plant make the best possible use of it. Distribution could be set up on a joint basis through participating members of the industry. Similarly proven plants could be established in natural collections and freely available registers of such collections produced. One hears tales of choice plants collected in the wild or from chance seedlings or from a breeding programme being distributed and hidden away or possibly lost in little known gardens. It is vital for the industry and for conservation that this loss to all of us must be stopped. New and improved plants should be freely available to all. Is there a role for IPPS in all this? Yes, there most certainly is. We "Seek and Share" our knowledge of propagation; we must communicate and distribute information and generate enthusiasm to ensure that no opportunity is lost. I am hopeful that at the end of today's session we will have resolved to improve relationships with all parties involved in the quest for better plants.

UNIVERSITY OF BRITISH COLUMBIA BOTANICAL GARDEN PLANT INTRODUCTION SCHEME

A. BRUCE MacDONALD

Botanical Garden
University of British Columbia
Vancouver, B.C. Canada

(See Western Region, page 121)

THE COMMERCIAL EXPLOITATION OF NATIONAL PLANT COLLECTIONS

A.D. SCHILLING

The Royal Botanic Gardens, Kew, Wakehurst Place, Ardingly, Haywards Heath, West Sussex, RH17 6TN

In order that I may relate my subject matter to a personal level of experience I have restricted this paper to the national plant collections I know best — namely those of The Royal Botanic Gardens of Kew and Wakehurst Place.

It would be tempting also to give wide attention to the many other national collections which our islands hold, such as the many National Trust properties, the Royal Botanic Garden, Edinburgh, plus its three annex gardens and the various arboreta managed by the Forestry Commission (Westonbirt, Bedgebury, etc.)

The mother station, Kew Gardens, by the banks of the Thames at Richmond near London is world renowned, covers 300 acres and has a long and fascinating history. Much of that history is related directly to the subject of commercial exploitation of plants.

Kew's annex garden (Wakehurst Place, Ardingly, Sussex) is almost 500 acres in extent, and within its 14 mile boundary it nurses a very rich and varied collection of temperate plants with accent on species from Asia and the southern hemisphere. It also includes a 125 acre botanical reserve for the conservation of the flora of the Weald, and a well-established Seed Bank.

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To the uninitiated visitor, Kew is seen as a glorified public park but it is, of course, first and foremost a national botanical research institution with many different responsibilities. These include the studies of taxonomy, cytology, physiology, palynology, and biochemistry. The Herbarium and Library hold the largest collections of their kind in the world, and the Museum Division curates, represents, and exhibits the immense wealth that economic botany offers for the use of mankind.

Historically, Kew has much to be proud of and has been directly involved in many projects which over the years have afforded long-term benefits to commerce both at home and overseas.

Economic botany and agriculture have worked together via Kew's long-standing quarantine service, and growers of cocoa, coffee, cotton, rubber, bananas and sugar have benefited in consequence. The rubber plant (*Hevea brasiliensis*) was originally introduced to Asia from Brazil via Kew glasshouses and has since revolutionized the economies of both Sri Lanka and Malaysia in particular.

Earlier still, in 1789, a Kew botanist, David Nelson, was sent in quest of the breadfruit, *Artocarpus altilis*, from Tahiti, but en route he had the misfortune to be cast adrift with Captain Bligh and died soon after he reached landfall in Java. A few years later two other Kew men, Christopher Smith and James Wiles, successfully obtained the breadfruit and introduced it to St. Vincent.

Kew and the world of economic medicine are also inseparable mainly because of a plant named *Cinchona*. The various species of this South American genus were introduced to India via Kew thanks to the bravery and persistence of Cross, Markham, Spruce and others who risked life and limb to despatch seed and seedlings from the slopes of the Andes to the quarantine houses at Kew. A few years later a life-saving dose of quinine was being sold throughout India for the equivalent of "half a farthing". Today, a branch of *Cinchona* is incorporated in the Armorial Bearings of The Kew Guild in order to signify the Garden's important links with economic botany.

These few random examples of past endeavours serve to illustrate what economic results have stemmed from the various activities of Kew, but what about the endeavours of the present and future?

The Seed Bank, based at Wakehurst Place, is a section of Kew's Jodrell Laboratory. It stores millions of seeds of wild plants from all over the world in refrigerated containers. Many of these seeds are potential crops for the Third World and scientists from many countries may draw on the bank for

research into such topics as forage production, chemical extracts, cancer control, etc. Its commercial potential is therefore enormous.

Extracts from the seeds of a legume (*Dolichos biflorus*) is invaluable for swift blood grouping. When mixed with blood samples this extract ignores more common groups and reacts within seconds to red blood cells of Group A1. In consequence, the National Blood Transfusion have been rapid in making use of this technique.

The tropical mucuna bean (*Mucuna* spp.) holds a high concentration of the drug known as L-Dopa, which is used for the treatment of Parkinson's disease. All the various herbarium holdings of this plant have been screened in order to gain an extensive knowledge of the species' natural distribution. Seed has since been obtained from each known area in order for the various L-Dopa concentrations to be compared from each population. Mucuna is now being commercially grown in Paraguay and elsewhere.

Biochemical research at Kew is also being pursued in the field of natural insecticides. Because of escalating production costs, and for various safety reasons, synthetically based insecticides are currently falling from favour and what has already been done by the use of extracts from *Pyrethrum* is now being attempted by researching into the use of other plant by-products. Recent results indicate that certain isolated plant chemicals deter such important pests as locusts and beetles.

One of the most recent, important and far reaching projects taken up by Kew is the one known as SEPASAT (The Survey of Economic Plants of the Arid and Semi-arid Tropics). This is backed by funds from OXFAM and is designed to identify plants which will be economically valuable for culture in desert and semi-desert regions, regions which amount to almost half the land surface area of the world.

The Herbarium and the Economic Botany section of the Museums are being screened for plants which could be useful for food, fuel, forage, resins etc., and over the last 18 months 3,500 plants have been listed for their potential value.

From the point of view of this paper the commercial horticultural exploitation of Kew's collections is normally directed towards what is now termed, "The Living Collections Division."

This division of Kew Gardens is the Kew which the public knows best. Its collections hold over 120,000 accessions representing almost 50,000 different types of plants encompassing 352 families and 5,465 genera. Collectively these make up a living reference collection for scientific research, for pleasur-

able visual enjoyment, for educational purposes, and for the commercial horticulturist to visit for plants of new, forgotten, or unusual potential.

Everyday the L.C.D. despatches living plant material to the four corners of the world in support of plant breeding programmes and for many other reasons besides. The collections hold increasing stocks of wild collected authenticated species (over 6,300 accessions in 1982) and regularly propagates and distributes rare and endangered plants. These are raised conventionally, or by way of tissue culture in the Micropropagation section.

Bulking-up limited stocks of rare or endangered plants is now a rôutine operation for it has been proved that the best way to keep a plant securely in cultivation is to propagate it and then distribute it as widely as possible.

One current project of particular interest is the part Kew is being asked to play in the compiling of a computerized genetical stock list of *Malus* species. This project, which is based in this country at East Malling Research Station, is a complex and international one. It is backed by a division of the United Nations Food and Agriculture Organization (FAO) in Rome, namely the International Board for Plant Genetic Resources (IBPGR), as well as by the fruit section of the European Association for Research in Plant Breeding (EUCARPIA). From this project it has been realised that Kew's collections hold at least 34 different *Malus* species which are of significant scientific interest to the project.

Wherever possible Kew attempts to represent a species from as wide a range as possible, even to the extent of sometimes deliberately growing what one might consider to be an inferior or poor form in order to exhibit the range of variation.

In contrast, a commercial nurseryman usually restricts his stock to plants of a high and immediate amenity value. He selects his plants deliberately with an eye for certain visually appealing qualities such as a dwarf habit, the colour of foliage, the long flowering period or winter hardiness. In other words, he clonally selects and generally narrows down the genetic variation of his material, seeking uniformity and consistency of stock. Obviously there are exceptions to these rules such as the mass production of plants from seed (*Betula pendula*, *Berberis wilsoniae*, etc.).

From these two generally opposite philosophies it is at first difficult to understand how botanic gardens and commercial nurserymen can have any common ground upon which to communicate, but of course they do.

Botanical gardens usually cultivate a plant for at least one of the following three reasons:

1) its scientific and research value or potential

2) its educational value

3) its amenity or aesthetical value

The common denominator which links botanical gardens to commercial horticulture obviously comes under the third of these headings, namely amenity.

Plants of potential commercial interest could be a species, a sub-species, a variety or form, a clone of a natural or deliberate hybrid, a mutation or a sport. Whatever it is, if it is attractive and qualifies for that somewhat meaningless but all important title, "a choice plant", then it appeals to the eye, the aesthetic senses and, most pertinent of all, the financial instincts of the nurseryman.

It could seem to the commercial world of horticulture that holders of national collections such as Kew could do more than they do to guide and assist those who are willing and interested to exploit a new or little grown plant.

On the other hand, it could perhaps be just as readily argued that the commercial grower could do a lot more to help himself by using our living reference collections more readily. After all, if one requires knowledge from a book one visits a good library. The fundamental difference is, of course, that one can generally only *borrow* a book, whereas with an interesting plant one usually wishes to possess and keep it and, of course, by pursuing the official channels, one invariably can. Last year alone, Kew distributed over 5000 surplus natural-source seedlings to other arboreta and specialist collections, and outgoings of material for all purposes have recently doubled.

Commerce commonly sells the public the idea that a new car model is something to be desired, so why doesn't the nursery trade sell similar but far more worthy ideas to the gardening public? All too often the easy line is taken, of restricting one's stock to the popular plants which the public already knows and demands, and they probably only demand them because they are unaware of the alternatives.

× *Cupressocyparis leylandii* is currently produced by the million for screening off one Englishman's castle from the one next door. Now it looks as if suburbia is about to be smothered by a sub-topian carpet of the two golden Leyland cypress clones, 'Robinson's Gold' and 'Castlewellan'.

What is wrong with selected forms of × *Cupressocyparis notabilis*, *Chamaecyparis lawsoniana*, *C. nootkatensis*, *Thuja*

plicata, *Tsuga heterophylla*, and our native yew, *Taxus baccata*? None of these are particularly slow-growing in spite of what is stated to the contrary. What price speed? All the leisure time one is supposed to have as a result of labour-saving devices in homes and gardens doesn't really give the individual all that more real spare time for doing other things. Does it *really* matter if a newly planted hedge takes a couple of extra years to fill out? We live in an age of quick foods, cash and carry service, instant take-away meals and built-in obsolescence in much of the machinery we purchase. Must we really add instant gardening to the list? Gardeners are by tradition a patient breed of people, so why do they need to be subjected to the near-frantic pressure for "the immediate"? Surely the desire to grow something different is a far more noble goal to aim for. I would welcome the birth of a late 20th century equivalent of the 19th century game which the arboretum owner played by way of his harmless "one-upmanship" gardening philosophy. The mature glories of these games now give an enormous amount of pleasure to the gardeners of today — Westonbirt Arboretum, Borde Hill, Hergest Croft, Dawyck, Benmore, Bicton — the list is almost endless. Why not a new version of the old, already proven, game but for the majority instead, and with higher returns for those who produce the articles necessary for it to be played?

The small garden owner can be encouraged to be "a plant ahead" of his neighbour (some already do play this game) and nurserymen can fuel this fashion by tempting the players with new and interesting plants as necessary. Why not a "Plant of the Week" in the local Garden Centre instead of the "Car of the Week" in the garage showroom down the road?

Forgotten plants are coming back into fashion and new plants are coming to light all the time. Two notable recent introductions are *Diascia rigescens* and *Phygelius aequalis* (yellow form), both coming from South Africa but hardy enough for our milder counties at least.

The Royal Horticultural Society rare plants sales area at Wisley is doing brisk business by selling material which is generally difficult to come by elsewhere, and other specialist nurseries are giving a similar service to the more discerning gardener.

I know of at least one well-established and respected nurseryman who not only sells unusual plants, but actually organises his own expeditions in order to add to his stock. Taking things a step further, it could be suggested that those who do decide to grow wild collected material from legitimate sources might well pay more detailed attention to collecting records. A

plant collection's number is not a sign of ego or a quaint snob factor, it is a means of precisely identifying a given collection. If it is lost from a plant it can seldom be relocated. Careful attention to names is also important. I have known of several amusing mistakes being made through lack of care, the best perhaps being when the Award of Merit form of *Rhododendron arboreum*, known as 'Rubaiyat', was written as 'Rubber Mat'.

Although I am critical of those who hold extremely limited stock, the case against overspecialisation must not be left unmentioned. I know of one very knowledgeable grower who specialises in just one or two tall growing woody genera and then complains long and hard that there is not a market for his plants. I have even known those who complain that botanic gardens don't buy their plants, seemingly oblivious to the fact that such institutions have little justification to oblige as they are a part of an international seed exchange system. They have many other scientific-based sources of supply besides. Exceptions are invariably associated with a desire to obtain a cultivar or, less likely, a species which is for political reasons currently unavailable through foreign negotiations. Obviously it is not possible for all and sundry to join the specialist market, for the demand simply isn't big enough. Not yet that is; given time and the opportunity to realise that there is more to gardening life than *Hypericum* 'Hidcote', *Rhododendron* 'Pink Pearl' and *Rosa* 'Super Star', the buyers of plants will, little by little, become more discerning and demanding in their tastes. The nursery trade should, therefore, think about the idea of carefully adding new plants to their stocks and, if the balance and sales technique is right, surely the extra returns will be forthcoming.

First and foremost, the commercial nurseryman's enterprise must be profitable in order to thrive and survive. If the profit margins turn out to be good enough, then why not diversify, and do the profession even more good?

National collections are institutions to be referred to and, within reason, to offer assistance and advice. Unfortunately, they rarely have enough time or resources to send out staff to act as travelling salesmen, except on special occasions when invited to address specialist bodies such as the I.P.P.S.

SUMMARY OF DISCUSSION

There is no equivalent to the U.B.C. discussion groups in Britain. The Royal Horticultural Society gives the Award of Garden Merit to deserving plants, and the National Council for the Conservation of Plants and Gardens is making national

collections of 60 genera around the country. Lists of these collections may be obtained from Donald Duncan at Wisley. The response to the Long Ashton Clonal Selection Scheme has been disappointing, as this is designed to select the best clones for commercial adoption.

There were conflicting views over the scope for further collecting of plants from the wild. Some held the view that there was still enormous potential in reselecting plants from the wild for specific characteristics such as hardiness or use in plant breeding. Many sources had not been fully exploited, even North America. The other view was that new plants would have to be genetically manufactured, as there was not much new material left in the wild.

On the whole botanists did not have any interest in the nursery stock industry, and nurserymen should seek out plants in Botanic Gardens. It was felt that positive action was needed to bring together all parties interested in the collection and dissemination of new plants.

LEAF SPOT DISEASES OF COMMERCIAL ORNAMENTAL PLANTS — THEIR RECOGNITION AND CONTROL

DON GILBERT

Agricultural Development and Advisory Service
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Brooklands Avenue, Cambridge

The taxonomy of fungi is a difficult topic. In the fungi there are some 47,000 known species. Imperfect fungi, with no known sexual stage, account for 15,000 species and many of these are capable of producing leaf spots.

While we might agree that disorders such as Black Spot of roses (*Diplocarpon rosae*), Leaf Blotch of chestnut (*Guignardia aesculi*), and Leaf Spot of willow (*Marssonina* spp.) should be easily recognised by horticulturists, I feel that this generalisation is incorrect and misleading. Advisory experience has taught me that the services of a mycologist is required to obtain a correct identification of leaf spot disorders.

Leaf spot of willow, for example, may be caused not only by *Marssonina* spp. but also by *Ascochyta*, *Cercospora*, *Cylindrosporium*, *Phyllosticta*, *Ramularia*, *Septoria*, and other fungi. There are more than 100 species of *Cercospora*. Regular control measures should not be considered until identification of the disorder is certain.

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Traditionally, nurserymen have not adopted regular spraying with fungicides to protect hardy ornamental plants from leaf spot disorders. However, I believe customers will increasingly demand only blemish-free plants. Good quality will mean the absence of leaf spots, blotches, or other disorders. This level of control may require up to 12 spray applications a year using fungicides to protect growth which develops between sprays as well as existing foliage.

Many leaf spotting disorders thrive in the moist, warm environment created by plant propagators, and selecting disease-free stock for propagation must be the first priority if control of disease is to be taken seriously.

I have selected the following examples of leaf spotting disorders to illustrate my topic, with suggested control measures.

CROP	DISORDER	CONTROL*
Rosa	Blackspot — *Diplocarpon rosae*	Captan, Mancozeb, Maneb (A)
Berberis	Bacterial leaf spot — *Xanthomonas berberidis*	Copper (Streptomycin in U.S.A.)
Acer	Leaf spot (purple eye) — *Phyllosticta minima*	Zineb, Delsene M
Hebe	Leaf spot — *Septoria exotica*	Dithiocarbamate
Rhododendron	Leaf spot — *Gloeosporium rhododendri* (20 other fungi cause leaf spots on Rhododendron)	Benlate
Pyracantha	Leaf spot — *Fabraea maculata*	Don't know
Aesculus	Leaf blotch — Guignardia aesculi	Daconil, Sportak, Tilt — used in ADAS trials at Wye.
Camellia	*Glomerella cingulata*	Trials in Guernsey and Efford EHS with Sportak
Salix	Leaf spot — *Marssonina kriegeriana*	Morestan
Bergenia	Leaf spot — Colletotricum spp.	Copper, Captan
Mahonia	Leaf spot — *Phyllosticta* spp.	Delsene, or pick off leaves.

(A) = Approved under Agricultural Chemicals Approval Scheme

* = For the purpose of this paper control should be read to mean 'This fungicide may control the disease but you should seek further advice on the use of the fungicide BEFORE carrying out your own trials. In the first instance treat only a small number of plants to check crop safety and efficacy.

MONOCHAETIA KARSTENII — A LEAF DISEASE OF CAMELLIA

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INTRODUCTION

Camellias form a specialist line of work in the experimental programme at Efford, particularly in relation to developing an accelerated production schedule for well branched, budded plants in 2 to 2½ years. However, all camellia trials came to an abrupt halt in 1977 due to the loss of a large proportion of the young plants which developed a progressively worsening leaf drop and subsequently died. The problem was not initially associated with disease as the early symptoms of leaf scorch on the young foliage was similar to that observed when levels of nutrition were excessive, or sun scorch from water splashes, and no fungal bodies could be found on the damaged tissue. The problem persisted and intensive work by pathologists eventually identified the cause as fungal. The organism was originally thought to be *Pestalotiopsis guepini*, but more recently has been identified as a closely related species, *Monochaetia karstenii*, which was considered only weakly pathogenic, capable of colonising wounded or damaged tissue, but not a serious problem. In any event, experience has shown that if allowed to build up unchecked it causes major problems in young plants, particularly where they are under stress in propagation or in the increasingly intensive production schedules used today.

THE DISEASE

In a severe outbreak on young plants symptoms are first seen as a leaf "scorch", followed by premature leaf drop, stem die-back, and often plant death. In less severe cases plants can recover after initial leaf drop. The "scorched" area is not the typical brittle scorch, the leaf remaining soft and pliable as the die-back continues, and mention has already been made that no fungal spores can be detected on these areas, even under a lens. The source of infection is found on the lower, older leaves, especially if they have been damaged or trimmed during propagation. Here the more typical necrotic areas which develop adjacent to damaged tissue are covered with black pinhead-sized fruiting bodies of the fungus (acervuli). Each acervuli contains thousands of spores which can be spread in air currents and water splashes.

Once identified it was realised that the disease was widespread and many of the leaf drop problems on *Camellia* were possibly associated with the disease. On most nurseries it could be found on the lower foliage of older plants and was not causing any untoward problems on these larger plants, except as a source of inoculum for infecting younger plants when conditions were right. Where levels of inoculum were allowed to build up, conditions adverse to plant growth favoured progress of the disease, at which stage it was capable of infecting healthy tissue of young plants causing serious trouble. The epidemic at Efford in 1977 was related to the very hot season of 1976 which produced severe plant stress, together with a range of experimental treatments, several adverse to growth.

Since the disease is endemic it has to be lived with, but improving cultural techniques and use of fungicides can help reduce the disease to manageable proportions.

IMPROVED CULTURAL TECHNIQUES

All possible steps should be taken to improve hygiene and minimise factors causing stress to young plants to enable them to resist infection.

Factors to consider include:

1. **Stock Plants.** Stock plants can be a major source of infection as sporing bodies can overwinter on dead flowers or in stem lesions as well as on the foliage. The presence of the disease is not usually a problem as far as stock plant growth is concerned, but provides a source of inoculum which can be a problem during propagation. Routine hygiene measures for stock include:

a. Removal of dead flowers (from plant or off the ground).

b. Removal of diseased foliage.

c. Routine fungicide programme, but especially just prior to taking cuttings.

2. **Propagation.** Since stress is severe during propagation this stage is at greatest risk for fungal infection and needs close attention to detail.

a. As with stock plants, routine hygiene measures are fundamental, with regular inspection to remove dropped leaves as they provide a prime site of initial fungal infection.

b. Leaves of cuttings should not be trimmed as this provides an entry point for wound pathogens. Trial results have clearly identified trimming of leaves during propagation as one of the major sources of infection of *Monochaetia karstenii* on young plants.

c. Routine fungicide spray programme, particularly for winter material under polythene covers as this environment is ideal for fungal growth.

3. **Young Plants.** Promotion of active growth in the liner stage and during the first season of growth in larger pots is important and can be achieved by:

a. Prevention of salt accumulation from too high a rate of fertilizer.

b. Do not overdose phosphate. Too high a rate of base phosphate will cause severe stress in young plants.

c. Prevent waterlogging and root death by improving compost structure. Granulated pine bark looks promising as a means of improving compost drainage and aeration.

d. Do not water with overhead spray lines. The higher humidities and water splash increase the risk of disease spread.

Plants at Efford have been successfully grown on either low level irrigated sand beds or benches, or by using pot drip irrigation on a weldmesh bench. The drier atmosphere of the latter method is particularly suitable where disease risk is high.

e. In periods of high light intensity (and temperature) shade the crop to reduce stress.

f. Use chemical pinching agents with caution as their mode of actions can increase plant stress.

g. Routine fungicide programme used for plant protection.

FUNGICIDE PROGRAMMES

A range of chemicals have been screened for both phytotoxicity and effectiveness in controlling the disease, in cooperation with the Glasshouse Crops Research Institute and the Agriculture Development and Advisory Service plant pathologists. Only three of those screened in these trials were effective without proving phytotoxic on the limited range of camellias used.

1. Benomyl (Benlate) appeared to give some protection against infection, but did not eradicate the disease.

2. Prochloraz (Sportak) and carbendazim/maneb (Delsene M) appeared to have potential both in protection and eradication or reduction of inoculum levels, but neither have Approved Label Recommendations for such use.

However, because of the high level of endemic *Monochaetia* inoculum at Efford, both chemicals are used as protectant

sprays in routine fungicide prgrammes at the rate of 1 g product/litre applied to run off.

a. Stock Plants: Rotation of prochloraz and carbendazim/maneb at monthly intervals during growing season, ensuring an application just prior to taking cutting.

b. During Propagation: Rotation of prochloraz, captan, benomyl, carbendazim/maneb and iprodione (Rovral) at fortnightly intervals.

c. During liner and first season of growth: Rotation of prochloraz and carbendazim/maneb at monthly intervals during the growing season, reducing to 2 to 3 month intervals during the autumn and winter.

CONCLUSION

Once a crop is infected with *Monochaetia karstenii* it is difficult to eradicate and use of fungicides alone will not give control under adverse growing conditions. Prevention is the most effective control, and much can be achieved by improved culture such as routine hygiene measures together with attention to detail in the production schedule, promoting active growth, and reducing as far as possible the factors causing stress. Once these measures are adopted fungicides become an important aid as a further means of protecting the plant against infection.

CONCERNS WHEN PROPAGATING PLANTS FOR THE URBAN ENVIRONMENT

JOHN A. WOTT

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The world population continues to grow and with it the demand for resources. The United States, the land of "never-ending" resources, is now also concerned about resource depletion, population growth and control and, most recently, people living in close proximity to their neighbors. These concerns, first discussed in greater degree in the 1960's, have lead to the simultaneous interest in and development of scientific programs called urban horticulture. They are concerned with the study of the interaction of people and plants in urban environments.

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Traditional horticulture, being a part of agriculture, has developed systems whereby we can study and/or produce uniform plants of a single cultivar in large numbers within defined and controlled environments. These systems provide the consumer with plants of similar size, flowers, and harvest time. They are ideal for the massive uses intended.

However, each urban garden is different. An urban garden contains plants grown alone or in small groups in confined and often changing environments. The selection and management of such gardens requires new tools such as modeling techniques now available in our "electronic" age.

The implications for the critical selection of plants for these urban gardens are immense. The plant propagator, the person who often determines whether a plant is even available, will continue to be an even more vital person in the total scheme of getting plants from propagation to the ultimate consumer in the urban environment.

Areas of Concern. The selection of plant material begins with the individual plant's genetic make-up. In urban gardens, plants will be selected for their function (adaptability) as well as beauty. Traditionally, botanic gardens and arboreta have emphasized the species concept. In urban landscapes, more attention will be given to cultivars and varieties. Often these plants will come from amateur hybridizers or other plant enthusiasts. But we must collect and correctly classify these plants, so they can properly be introduced and named for the trade.

Increasing awareness for color, form, and texture contrasts will be necessary. The variegated foliages, distorted branching habits, or unusual flowering and fruiting habits will offer gardeners more contrasts in design. Many of these plant forms are already existing, but their specific adaptability for urban environments has not been defined.

Also the enthusiasm of the urban gardener (hobbyist) for specialty plants must be noted. Increased interest in unusual plants such as hardy perennials and cycads is specifically shown by the growth of local chapters of the Hardy Plant Society and the Cycad Society in the Pacific Northwest area. These plant society members will "sell" the use of these plants, but they will require the help of horticultural trained personnel in the selection of their propagation and cultural problems.

Urban gardens will require small plants for their smaller spaces. Thus more emphasis will be placed on dwarf and compact growing types. These types are often more difficult to

propagate and are usually slower to reach a saleable size. The propagator will be challenged to develop a system which efficiently produces these plants and even to obtain initially faster growth, perhaps through the use of chemical controls.

Basic botany informs us that plants need light to conduct photosynthesis. Furthermore, it's common practice to classify plants as shade or sun-loving. However, recent studies now indicate that light quality as well as quantity may affect the structural formation of leaves, nodal branching, and linear growth of plants. Much of our knowledge in this area comes from research with interior foliage plants. However, interior plants are really outdoor plants from subtropical and tropical areas. Therefore these light studies should begin to help us with our urban garden situations. In the future, specifications for plants in urban gardens may include requirements for propagation and production under specific light regimes, such as no direct sunlight, or highly reflected light (heat tolerant).

Moisture content of the soil is another consideration when selecting plants for urban gardens. The soil moisture supply will vary within even small areas of the landscape. Areas under eaves usually receive little rainfall and northern exposures of buildings as well as areas close to foundations are usually drier. Thus a plant moved as little as six inches in one direction can have a very different moisture site.

Urban planting sites have been excessively disturbed, and often are composed of only fill soil. This means that normal capillary water movement within the planting area is impaired. In such conditions, it has been most acceptable to amend these soil sites. But, modern theories now indicate we should select plants which can tolerate these unamended soil sites. Current studies involving mycorrhizae and plants which "fix" nitrogen will continue to tell us which plants have the potential for such sites. In addition, special techniques for the propagation of these plants may also be necessary.

Rainfall is usually sparse or even non-existent during the summer in many parts of the United States. Most of the landscape plant materials now used in such areas require summer irrigation. However, no one, even Pacific Northwesterners, are immune to water restrictions. Our planting designs will require the selection of more drought-tolerant plants as well as the implementation of efficient irrigation systems to conserve water.

All gardeners know that plants are ecotypically adapted to specific climatic zones; e.g., tropical, alpine, etc. However, astute gardeners also know that specific plants sometimes can tolerate a wider range of temperature conditions. In urban

gardens, extreme temperature fluctuations can occur. Thus the plants most useful in urban gardens must be able to tolerate such fluctuations.

Often plants appear to be growing normally, but still may be under some type of environmental stress. For instance, the white bark birches seem to grow satisfactorily in the central midwest. However they are very susceptible to bronze birch borer which seems to be related to stress. In more northern climates where the trees are not stressed, the borer problems are non-existent. In our future plant decisions, we will be concerned with total plant management systems. The new and growing program such as IPM (Integrated Pest Management) will help us decide which plants will be useful for specific stressful environments.

Market analysts tell us that today a larger number of landscape plants die after they are planted in the landscape than in the propagation-production phase. Many horticulturists feel this loss is not primarily due to the gardener's lack of or poor care. The problem may be concerned with the method in which the plant was originally propagated and/or grown.

Researchers are obtaining data which indicate that growing plants under "ideal" schemes may not be best for later adaptation into the urban environment. Studies are underway to determine if plants produced under "stress" will be better able to adapt to the adverse environment under which they will ultimately need to flourish.

Plants in urban gardens are also planted closely together. The study of allelopathy and the effect of one plant on another is now receiving increasing emphasis. Urban garden specifications of the future may well include schemes for companion plantings within all areas of landscape plants.

SUMMARY

In the past, landscape plants were primarily selected for their esthetic features. But modern plant selection will also consider the specific function/s the plants can perform; i.e., for an architectural, engineering, culinary, or climate control function.

Our smaller and more intimate urban gardens of the future will be viewed from a closer range. With closeness, the finite details of the plants are more noticeable. Plants with more delicate characteristics and less vibrant color will be necessary. Also, these gardens will offer the opportunity to use plants which appeal more to our senses.

In our futuristic selection and propagation of plant material, we will incorporate the esthetic and functional merits of the plants into creating an environment unique for the needs and lifestyle of each gardener. We will be creating our new smaller gardens with an even greater sensitivity for the type of plant material used. It is our responsibility as propagators to provide this plant material in an efficient and useful manner.

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NEW HERBICIDES FOR THE NURSERY INDUSTRY

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We categorize herbicides as pre-emergence (those applied prior to seed germination) and post-emergence (those applied to existing weeds). Among the best of the Federally registered herbicides in the U.S. are the following with a brief statement as to why they are being used extensively.

PRE-EMERGENCE HERBICIDES

Dichlobenil (Casoron) is definitely not new, but the most *effective pre-emergence herbicide for control of perennial* weeds in field (not container) nurseries. The use of post-emergence herbicides such as glyphosphate have reduced the use of this product in recent years. It is volatile and its use is limited to autumn and early winter when soil temperature is 50°F or lower.

Napropamide (Devrinol) is one of the newer products used in container nurseries because it effectively controls chickweed and groundsel, two very troublesome weeds. Napropamide is alternated with Oxadiazon (Ronstar) in container nurseries but is also registered for field grown trees, deciduous

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shrubs, evergreens, and ground covers. Incorporate with tillage or irrigation.

Metolachlor (Dual) — Quite new and not used extensively yet by nurserymen but effective for the control of most annual grasses and yellow nutsedge. To increase effectiveness, apply with Simazine (Princep) to control broadleaf weeds in field grown nursery stock.

Oryzalin (Surflan) — Similar to Treflan in weed control and safety but does not have be soil incorporated. This can be used in existing plantings. Use to control annual grasses, chickweed, purslane, lambsquarters, and pigweed, Oryzalin is labelled for use with shrubs, evergreens, ground covers, and flowers. It is becoming a more popular pre-emergence herbicide used by itself or in combination with Simazine or Glyphosate.

Oxadiazon (Ronstar) — In the past 5 years this material has become the number one container pre-emergence herbicide. It is effective against bittercress, common groundsel, galinsoga, smartweed, woodsorrel (*Oxalis*) and barnyardgrass, but not chickweed. Avoid application to wet foliage to prevent granules from attaching to the leaves and causing phytotoxicity.

Oxyfluorfen (Goal) — Effective against a wide spectrum of annual broadleaf weeds and annual grasses in conifer seedbeds, conifer transplants, and conifer container stock. Controls bittercress, groundsel, chickweed, and barnyardgrass, all difficult to control with other products.

Oxyfluorfen combined with Pendimethalin (Prowl) and marketed as Pro Grow Ornamental Herbicide II, is registered for a wide variety of field and container grown stock. The combination controls oxalis and spurge in addition to those weeds mentioned for oxyfluorfen alone.

Pronamide (Kerb) — Although this product is not new, it must be included because it is very effective in controlling perennial grasses and selected broadleaved species such as *Rumex* (dock). It can be applied directly to the existing weeds without cultivation. Most effective when used in combination with Simazine in autumn or early winter.

Simazine (Princep) — The standard herbicide against which all other products are compared. Controls annual grasses and broadleaved species. We recommend a 2.0-3.0 lb AIA application in autumn followed by a second treatment at 1.0-1.5 lb AIA in spring in combination with Napropamide, Dual, or other products effective against annual grasses. Usual-

ly not used in containers but is the standard for *Taxus*, shade and flowering trees, and many other crops.

POST-EMERGENCE HERBICIDES

Asulox (Asulam) — A systemic herbicide which controls annual grasses when applied as an over the top spray on juniper and *Taxus* only. It requires 4 to 6 weeks for effective control but this is longer than most nurserymen are willing to wait for weed control.

Fluazifop-butyl (Fusilade) is a recently labelled post-emergent herbicide that controls grasses but not broadleaf weeds. This is an over-the-top treatment which is safe to use with a broad range of woody landscape crops. Apply to grasses at 2 to 6 in. in height or before they become 18 in. high. The herbicide is slow to control the grasses, with 2 to 3 weeks an average time expectancy. Always use with a crop oil at rates on the label or a non-ionic surfactant.

Glyphosate (Roundup) controls annual and perennial grasses and broadleaf weeds. Use prior to planting or as a directed spray toward the base of certain plants. Most effective control of perennial weeds occurs when the weeds are in the flower bud or bloom stage of development. There is no soil residue.

Paraquat (Paraquat) is a contact herbicide used to control annual grass and broadleaf weeds in 2 to 3 days. A surfactant should be used. There is no soil residue. Use protective gloves while handling the concentrate to avoid contact with skin. Combined with simazine good residual activity can also be obtained.

Sethoxydim (Poast) is very similar in action to Fluazifop-butyl in effectiveness, use, and phytotoxicity. Poast has only 1.53 lb/gallon compared to 4.0 with Fusilade. Therefore, the dilution rates are different, as are the initial costs. However, in the final analysis both cost approximately $75 to treat an acre. Use at 20 to 25 gal/acre at 40 to 60 lbs pressure/sq. in. with crop oil for best control.

These herbicides represent only a portion of the 28 herbicides labelled for the nursery industry in the U.S. Many of those not described above, such as trifluralin, DCPA, EPTC, chloropropham, alachlor, 2,4-D, aminotriazole, and others are outstanding products but are not particularly new to the industry.

Remember when using new or older herbicides, read and follow label instructions including safety precautions. Store in original containers, in dry places away from children and pets.

If herbicides are swallowed, come in contact with eyes, or are absorbed to the point of showing symptoms call a doctor immediately. The most responsible person should supervise pesticide applications.

ADDITIONAL TRADE NAMES

Common Name	Trade Names
Pre-emergence	
Dichlobenil	Casoron, Decabane, Nurosac, Dylcomec
Metolachlor	Dual, Bicep, Codal, Cotoran Multi, Milocap, Ontrack, Primagram, Primextra
Oryzalin	Surflan, Ryzelan, Divimal
Oxyfluorfen	Goal, Koltar
Pendimethalin	Prowl, Herbadox, Stomp
Simazine	Princep, Aquazine, Cekusan, Gesatop, Primatol S, Simadex, Simanex
Post-emergence	
Asulam	Asulox, Asulox F, Asulox 40
Fluazifop-butyl	Fusalisade, Hache Uno Super, Onecide
Paraquat	Paraquat, Dextrone, Dexuron, Gramonol, Gramoxone, Gramuron, Herboxone, Pathclear, Terraklene, Totacol, Weedol

SUMMARY OF DISCUSSION

Questions were asked about control of marestail (*Equistum* spp.) in field-grown nursery stock. Various herbicides and methods were suggested, one being to use aminotriazole in August. Another was to apply glyphosate (Roundup) in late autumn, when foods are moved from the leaves down to the roots. The droplet size has an effect on "stickability", and Pollyfilla wallpaper paste mixed with Roundup to make a gel which can be painted on the weed works well. Another suggestion was to add diquat to the Roundup spray, as this enhances the effect on both marestail and bindweed.

A COMPARISON OF PROPAGATION UNIT SYSTEMS

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The objective of my investigation was to compare the rooting of hardy nursery stock in different types of propagation unit systems which are currently available to the industry.

The systems used were:

Japanese Paper Pot — paper containers in an expandable honeycomb form.

Vaca 40 — plastic tray insert with 40 sections.

A.P. 40 — polystyrene tray with 40 sections.

Speedling — polystyrene tray with wedge shaped cells.

Jiffy 7's — compressed peat blocks.

Rockwool — preformed into a seed tray with 45 rockwool blocks.

Control — standard seed tray.

Comparative costings of the systems were carried out in relation to the following points:

i) The initial cost of the system.

ii) The number of cuttings per square metre.

iii) Efficiency of handling.

iv) Speed and percentage of rooting.

v) The growth pattern and response of plant material when subsequently potted off.

Propagation material selected included difficult, moderate, and easy-to-root subjects. These were: *Chamaecyparis lawsoniana* 'Ellwood's Gold', *Chamaecyparis lawsoniana* 'Albospica', *Arbutus unedo*, *Prunus laurocerasus* 'Otto Luyken'.

Propagation was carried out in the autumn, under mist, with basal heat at 21°C. Cuttings were prepared in the appropriate manner and inserted into the prepared unit systems. The time and ease of preparation of each system was recorded.

Results showing rooting percentages of each species in the various systems are given in Table 1. Table 2 presents data on comparative costs, areas occupied, and preparation time for each system.

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[1] Winner of the G.B. & I. IPPS 1983 Project Prize.

Table 1. Rooting Percentage of Cuttings in Different Unit Systems.

	Japanese Paper Pot	A.P. 40	Vaca 40	Jiffy 7	Rockwool	Seed Tray	Speedling
Chamaecyparis lawsoniana 'Elwood's Gold'	98.2	—	100	66.1	94.4	100	100
Chamaecyparis lawsoniana 'Albospica'	42.2	7.5	37.5	48.2	31.1	40	—
Arbutus unedo	12.6	15	37.5	32	46.7	42	—
Prunus laurocerasus 'Otto Luyken'	94.3	65	100	80.4	100	100	—

Note: Some systems giving low rooting percentages may have shown better results if tested under a different propagation regime.

DISCUSSION

Japanese Paper Pots. This system gave good results for easy rooting subjects, but average to poor results for more difficult to root subjects.

Advantages:

i) Large number of cuttings per m^2.

ii) Minimum storage requirements.

iii) Hygienic — used only once.

iv) Pots easily separated, hence suitable for machine potting.

Disadvantages:

i) High initial cost, i.e. cost of plastic trays for the paper inserts.

ii) Difficult to fix and fill the sections evenly with compost.

iii) Unit difficult to handle — heavy and liable to collapse, especially when the compost is wet.

iv) The particular unit used (38mm × 76mm sections) was really too small for most of the cuttings with the exception of *Chamaecyparis lawsoniana* 'Ellwood's Gold'.

v) Fairly high cost per cutting — 1.5p (1.2p if plastic trays assumed to have a 10 year life). However, this needs to be offset against increased production and the smaller area occupied by each cutting on the mist bed.

A.P. 40. Propagation results were very disappointing, considering the low cost of the system (0.9p per cutting), and the ease of handling.

Table 2. Cost of Systems, Area Occupied, and Preparation Time.

Unit system	Area occupied by 1 unit	No. cuttings per unit	Cost of unit	Volume of compost per unit	Cost of compost*	Total cost of unit. (Compost + container)	Cost per cutting. (Compost + container)	Preparation time for each system, prior to insertion of cutting
Japanese Paper Pot	600mm × 400mm = 0.24m²	336	385 p	15 liters	120 p	505 p	1.5 p (1.2)**	5.0 min.
AP 40	237 × 375mm = 0.09m²	40	17	2.3	18	35	0.9 (0.7)	0.5
Vaca 40	237 × 375mm = 0.09m²	40	28	2.3	18	46	1.2 (1)	0.5
Speedling	370 × 660mm = 0.24m²	162	64	3	24	88	0.5 (0.3)	0.6
Seed Tray	237 × 375mm = 0.09m²	45	20	4.4	35	55	1.2 (0.8)	0.2
Rockwool	365 × 220mm = 0.08m²	45	58.5	—	—	58.5	1.3 (1.3)	0.2
Jiffy 7's	237 × 375mm = 0.09m²	28	68	—	—	68	2.4 (1.8)	0.8

* Based on compost cost 8p1 per liter

** The original figures calculated on a one year life. The figures in brackets give the estimated cost of the systems when each is given its expected lifetime span.

Advantages:

i) Light and easy to handle, with cuttings being easily removed for potting.

ii) Maximum contact with the base substrate.

iii) Hygienic — no contact between roots.

Disadvantages:

i) Problems of individual sections drying out, with the polystyrene acting as a barrier against movement of water in the tray.

ii) Problems of coarse rooting subjects rooting into the polystyrene. This could be avoided by earlier potting.

iii) Need to sterilise if used more than once.

iv) Large amount of storage space required.

Vaca 40. Rooting results were excellent for easy rooting subjects and average for more difficult subjects. Drainage does not seem to be a problem despite the small drainage hole in each section, neither does the lack of direct contact with the base substrate. Price per cutting is average at 1.2p.

Advantages:

i) Quick and simple to use. Light to handle.

ii) Hygienic. Used only once, and there is no contact between cuttings.

iii) Minimum storage requirements.

Disadvantages:

i) Problems of root curl on vigorous, coarse rooting subjects such as *Prunus laurocerasus* 'Otto Luyken', which may result in subsequent problems of root constriction.

Speedling. This system was really too small, so was only used for *Chamaecyparis lawsoniana* 'Ellwood's Gold'. Substituted by A.P. 40 for the other subjects.

Advantages and disadvantages similar to the A.P. 40 system.

Jiffy 7's. This was the most expensive system used, with a cost of 2.4p per cutting, plus the cost of peat to cover the base of the tray (necessary to prevent units drying out). The system was also the most expensive in terms of space required per cutting. Overall propagation results were poor to average, the only exception to this being *Chamaecyparis lawsoniana* 'Albospica', which produced the best results under this system.

Disadvantages:

i) Difficult to keep large cuttings upright.

ii) Tendency for the neck of the cutting to rot off, as the compost does not wash into the pre-made hole after insertion.

iii) Problems of maintaining the correct moisture level.

iv) Fungal growth on pots.

Rockwool. Propagation results were generally good, and it produced the best results for *Arbutus unedo*. However, it is a very unpleasant material to handle, causing irritation to the skin. Gloves should be worn, especially when separating the blocks for potting.

Advantages:

i) Hygienic, no soilborne diseases. A sterile medium.

ii) Easy to prepare.

Disadvantages:

i) Material unpleasant to handle.

ii) Unit system is floppy, difficult to transport and store. There is also the tendency for the blocks to become top heavy with large cuttings, and fall over.

iii) Problem of maintaining the system at the correct moisture level.

iv) Blocks can be difficult to separate, especially where the cuttings have rooted through.

v) Heavy callus formation can, in some cases, prevent root emergence.

Seed Tray (Control). Good propagation results were recorded.

Advantages:

i) Easy to handle. Quick to prepare.

ii) No problems of sections drying out, the compost is moist throughout the tray.

iii) Good root system formed, with no root curl problems.

iv) Cost per cutting is shown in Table 2 as 1.2p. This figure is based on annual replacement of trays. The actual life of the tray would probably be 10 years, depending on type of tray used. This would reduce the cost to approximately 0.8p per cutting.

Disadvantages:

i) Not hygienic — problem of transfer of soilborne diseases.

ii) Need for sterilisation if the trays are used more than once.

iii) Problem of root disturbance when the cuttings are potted.

Growth of cuttings after potting. As the investigation had to terminate at the end of the college year, it was not possible to draw any conclusions on ability of the cuttings to grow away after potting off from the different systems. At the time the project was concluded the only system showing any noticeable difference was the Rockwool cuttings being slow to get away.

CONCLUSIONS

The general conclusion drawn from my investigation was that the standard seed tray is still adequate for most nursery stock propagation, especially when potting is carried out by hand.

The seed tray produces good results at low cost. It has greater flexibility than the unit systems, allowing the number of cuttings to be increased or lowered, according to their size. Thus the mist bed can be used more intensively. Also one is not dependent upon a particular supplier for a particular system, with the associated problems of price increases or the supplier going out of business.

Where machine potting is employed, the Japanese Paper Pot may prove a more efficient system for pre-potting preparation of the rooted cuttings and for easier insertion of the cutting into the pot. However, a larger unit size would be required than the one used in the investigation for larger-leaved subjects and this may help to reduce leaf decay.

Unit systems may show a marginally better root establishment after potting, but the extra costs incurred when using a unit system may not be worth the increased expenditure, e.g. Japanese Paper Pot — 1.2p compared to 0.8p per cutting in a seed tray. This may be the reason why further investigations have not been carried out and why most nurseries still use the open tray technique.

PROGRESS IN MICROPROPAGATION OF WOODY PLANTS IN THE UNITED STATES AND WESTERN CANADA

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Until the mid-1970's most successful commercial micropropagation had been with herbaceous plant material. Several orchids, foliage plants, and strawberries had become commercially possible. A few woody plants were being micropropagated such as *Tupidanthus* and *Ficus*. But the majority of woody plant material still remained to be cultured. Perhaps the main reason for the lack of success with this group of plants, was that researchers were attempting to apply the techniques of herbaceous microculture to woody plants. Needless to say, the successes were few.

As pointed out by others (14), the microculture of woody plants is not a new development. In fact, in 1940, Gautheret (5,6) and Nobecourt independently of each other, using the newly discovered auxins, cultured cambial tissue of trees. Later, Jacquiot (7) conducted additional research on bud differentiation from cambial explants of several trees. In California, Ernest Ball (2), working with *Sequoia*, studied the differentiation of buds in cultured shoot tips. In France, Morel (11) had previously used these techniques in freeing certain plants from viruses. Through his research Morel discovered that, using a suitable medium, he could proliferate buds of orchids in a liquid-agitated culture. Shortly after, these techniques were used to commercially propagate many select orchids. With the discovery and synthesis of cytokinins by Skoog commercially successful micropropagation was possible. It was found that this group of chemicals was necessary for bud development in plants. Although no viable plants were formed from their work, the research of these individuals and others provided the basic knowledge for woody plant microculture. Further research was needed to determine the mechanisms controlling the growth and development of woody plants *in vitro*.

In 1964, *Populus tremuloides* was probably the first woody plant to be successfully cultured. Both shoots and roots were regenerated from callus (9). Winton (16) and Walter (17), separately, in 1968 reported on the formation of plantlets from aspen callus.

We, at Briggs Nursery, were fortunate that Dr. Wilbur Anderson (1) in 1968 was working on *Rhododendron* microculture. Dr. Anderson, one of Dr. Toshio Murashige's first students to work on woody tissue culture, came to work at the Northwestern Washington Research and Extension Center in Mt. Vernon, Washington. Progress on *Rhododendron* was slow, but the development of a low salt medium, use of an effective cytokinin (2iP), and a better understanding of what was controlling the adult/juvenile phase, provided the necessary information to culture these plants.

By the mid-1970's considerable research was in progress at several of the universities and commercial laboratories. Several graduates of Dr. Murashige were working on herbaceous and woody plants on the U.S. west coast. On a commercial level, Jiro Matsuyama (10) was working on a number of woody trees and shrubs. Dr. Mapes (8) of the University of Hawaii, a student of Dr. F.C. Steward (15), came to Oregon to work with the timber industry on trying to develop mass single cell production. In western Canada, Dr. David Lane was doing research on *Prunus*, *Malus*, and other woody plants. Dr. Robert Harris at the Saanichton Research Station in British Columbia, Canada, did considerable research on liquid media and heat treatment of cultured plants for elimination of virus. Dr. Richard Zimmerman of the U.S.D.A., Beltsville, Maryland was doing research with *Vaccinium*, *Rubus* and *Malus*. At the University of Wisconsin, Dr. Brent McCown was working with several species and hybrids of *Betula* and *Quercus*.

At the same time, encouraging progress had been made with certain species of gymnosperms: *Pinus* by Sommer and Brown (12,13), Tsai Cheng with *Pseudotsuga* (3) and *Sequoia* (2). At present, several woody plants have been cultured. Table 1 lists woody plants cultured either at commercial or research level with information as to their culture requirements and rootability in and out of culture. The list is compiled from a survey of approximately fifty researchers and commercial laboratories. With a better understanding of nutrient and hormonal requirements, many more plants will undoubtedly be cultured.

As with any business, for micropropagation to be successful good management is a must. In the long run, the well-managed labs will be the successful ones. In the future, closer attention will be paid to refining the growth requirements of the cultured plants. Methods for speeding the growth cycle and yield of plants in culture by altering the nutrient content

and culture environment will be studied. Economical forms of lighting and length, quantity, and quality of photoperiod will be investigated for major crops in culture. Efficient ways of handling the plants in and outside the lab will become more important. Refrigerated cold storage is already being used to store *in vitro* plant material for the following growing season. Perhaps with further research more of the conifers will be successfully cultured. Embryogenesis is exciting and has several advantages over conventional shoot tip micropropagation if it could be applied to a majority of woody ornamentals. As indicated by others (4) "fluid drilling" of plants could be possible without a hardening-off stage and providing a uniform true-to-name crop.

Micropropagation will increase in its importance to plant breeders. Anther culture can provide haploid material a breeder can use to study inheritance and produce homozygous breeding stock. With micropropagation, plants are becoming marketable much sooner and in larger numbers. This will, in turn, accelerate the development and improvement of several crops.

Table 1. Woody Plants in Microculture in the United States and Western Canada. (See key on page 247.)

Multiplication			Medium		Growth Regulator			Rooting	
Plant	Production	Research	High salt	Low salt	BA	2iP	Other	Multiplication to Soil	Stage III
Acer platanoides 'Crimson King'	9	15	9,15		9,15				9,15
A. rubrum 'Red Sunset'	15,24	15,24			15,24				15,24
A. saccharinum	15	15			15				15
Actinidia chinensis	18	17	17,18				17,18	18	
Aesculus glabra		23		23				23	
Alnus (several spp.)		19,23		19,23				19,23	
Amelanchier	10	4,17		4,10	4,10			10	
A. alnifolia	3		3		3			3	
A. arborea	10,12		12	10	10,12			10,12	
A. × grandiflora	3,10,12		3,12	10	3,10,12			3,10,12	
A. laevis	10,12	11	11,12	10	10,11,12			10,11,12	
A. stolonifera		11	11		11			11	
Arctostaphylos		19		19	19	19			
A. uva-ursi	3	17		3	3	3			3
Betula	2,3,15	4,5,12 13	12,15	2,3,4,5, 13	2,3,4,5, 12,13,15			3,5,13	2,15
Campsis radicans	18			18			18	18	
Castanea spp.	18			18			18	18	
Celtis occidentalis	10	14	14	10	10,14			10,14	14
Cercidiphyllum japonicum		4	4		4				
Chamaecyparis nootkatensis		4	4	4	4				
C. n. 'Pendula'		3		3	3				
C. obtusa 'Nana'		3		3	3				3
C. pisifera 'Boulevard'		13		13	13			13	

Table 1. Continued

Multiplication			Medium		Growth Regulator			Rooting	
Plant	Production	Research	High salt	Low salt	BA	2iP	Other	Multiplication to Soil	Stage III
Clematis armandii		3,17	3,17		3,17			3	3
		3,4	3,4		3,4		4(IAA)		
Corylopsis	3	4	3,4	4	3,4				3
Corylus avellana nut cvs.	15			1,15	1,15	1,15			1
C. avellana 'Contorta'		3	3	3	3	3			
Cotinus cvs.	3,12		12	3	3,12			3	3,12
Crataegus cvs.	12		12		12			12	
Daphne × *burkwoodii*		17	17				17		
		3		3	3				3
D. cneorum	4	2,3		2,3,4	2,3,4				3
D. mezereum	4			4	4				
D. odora	2	3		2,3	2,3			2	
Dirca palustris		13,23		13,23	13,23			23	
Eucalyptus	8		8						
Ficus benjamina	2,8		2			2			2
F. elastica 'Decora'	8	25	25		25				25
F. lyrata	2,8,21		2,21		2	21			2,21
Forsythia		5		5	5			5	
Fothergilla		12	12		12		12(NAA)	12	12
Garrya elliptica	3			3	3				3
Hamamelis		3,4,10,12	3,12	3,10	3,10,12		12(NAA)	10	3
Hydrangea		15,23	15	23	15,23			23	15
Ilex verticillata		21		21					
		23		23	23			23	
Kalmia latifolia cvs.	2,3,4,10 12,22,26	1,13		1,2,3,4, 10,12,13, 22,26		1,2,3,4 10,12,13, 22,26	1,4,12 22 (IAA)	3,4,10,13 22,26	1,2,3,13

Table 1. Continued

Multiplication			Medium		Growth Regulator			Rooting	
Plant	Production	Research	High salt	Low salt	BA	2iP	Other	Multiplication to Soil	Stage III
Lagerstroemia indica		23		23	23			23	
Lapageria rosea	3			3	3				3
Leucothoe	7			7	7			7	
Lonicera spp.		23		23	23			23	
Magnolia		3,4,9 10,15	3,10	3,4,9,10 15	3,4,9, 10,15	4		10	9
Mahonia aquifolium		2,3,19	2	3,19	3,19	2,19			2,3
M. repens		19		19	19	19			
Malus		13,14,17	14,17	13	13,14,17			13,14	14
fruiting cvs.	9,15	3,28	3,9,15,28		3,9,15,28			28	3,9,15,28
understock	3,9,15	25,28	3,9,15,25,28		3,9,15,28			3,9,28	15,25,28
ornamental	9,12,14	4,11	9,11,12,14	4	4,9,11,12,14			11,12	9,11,15
Nandina domestica									
'Carolina'	2		2			2			2
'Harbor Dwarf'	6,8,22	20		6,20	6,20			20	6,20
'Nana'		2	2			2			2
'Nana Compacta'	8,21		21		21	21			21
'Nana Purpurea'	6,22	2	2	6	6	2			2,6
Paeonia suffruticosa cvs.	6,10			6,10	6,10			10	6
Photinia		17							
Pieris japonica		4,17	4	4	4	4			
Pinus contorta		4	4	4	4				
P. eldrica		19		19	19	19			
P. taeda		27		27	27				27
Populus tremula 'Erecta'	10			10	10			10	
P. tremuloides	19			19	19			19	
Potentilla cvs.	3,5			3,5	3,5			3,5	

Table 1. Continued

Multiplication			Medium		Growth Regulator			Rooting	
Plant	Production	Research	High salt	Low salt	BA	2iP	Other	Multiplication to Soil	Stage III
Prunus avium (Mazzard)		17	17		17	17			
P. avium (Mazzard)	9		9		9	9			9
P. × *blireiana*	2			2	2				2
P. cerasifera cvs.	2,3,9, 15	25	3,9,15 25	2	2,3,9, 15,25	9			2,3,9, 15,25
P. × *cistena*	2,3,5,9		9	2,3,5	2,3,5,9		9 (IAA)	5	2,3,9
P. × 'Hally Jolivette'		11	11		11			11	11
P. persica	15	14,25	14,15,25		14,15,25				14,15,25
P. sargentii	4	2	4	2	2,4				
P. serrulata cvs.	2,3		3	2	2,3			3	2
P. triloba	2,3,9		9	2,3	2,3,9		9 (IAA)	3	2,3,9
P. yedoensis 'Akebono'		2		2	2				
Pseudotsuga menziesii		4,27	4	4,27	4,27				27
Pyrus spp.									
fruiting cvs.	9,15		9,15		9,15		9 (IAA)		9,15
ornamental	12,15	25	12,15,25		12,15,25			12	15,25
understock	9,15	25	9,15		9,15		9 (IAA)		9,15
Quercus		13,15		13	13				
Rhododendron	2,3,4,5 10,12,13, 14,16,21, 22,26	1,14,21		1,2,3,4,5, 10,12,13, 14,16,21, 22,26		1,2,3,4, 5,10,12, 13,14,16, 21,22,26	1,4,13 15,21 (IAA) 12 (IBA)	3,4,5,10, 12,13,14, 16,21,22, 26	1,2,3, 12,13 16
Azaleas									
deciduous	1,2,3,4,5, 12,16,22, 23	23		1,2,3,4,5, 12,16,22, 23		1,2,3,4,5, 12,16,22, 23	1,4,22 (IAA) 12 (IBA)	3,4,5,12, 16,22	1,2,3, 12,16
evergreen	3			3		3		3	

Table 1. Continued

Plant	Multiplication		Medium		Growth Regulator			Rooting	
	Production	Research	High salt	Low salt	BA	2iP	Other	Multiplication to Soil	Stage III
Ribes spp.	2			2	2				2
Rosa cvs.	3,19	13,21,23	3,19	3,12,21, 23	3,13,19, 21,23			3,13,21, 23	3,19
R. foetida 'Persiana'		19	19		19				
Rubus cvs.	2,3	1,14,25, 28	2,14,25	1,2,3, 28	3,14,25, 28	1		3,28	1,2,14, 25,28
Salix spp.	23	23		23	23			23	
Sequoia sempervirens	18	27	18	27	27		18	18	18,27
cvs.	3,4		4	3	3,4	3,4			3
Sequoiadendron giganteum	4			4	4			4	
Simmondsia chinensis	19	23	19	23	19,23			23	19,23
Spiraea	3			3	3			3	
Stewartia spp.		3,12	3	12	3		12		
Syringa vulgaris cvs.	3,12	4,23	3,4,12	3,23	3,4,12,23		12 (NAA)	3,23	12
Thuja occidentalis cvs.	4,5,13	3		3,4,5,13	3,4,5,13			3,5,13	
Tilia americana		23		23	23			23	
Ulmus cvs.	10			10	10			10	
Vaccinium angustifolium	7			7		7		7	7
V. angustifolium × *V. corymbosum*	23	23		23		23		23	
V. ashei	7			7		7		7	7
V. corymbosm	3,7			3,7		3,7		3,7	3,7
V. vitis-idaea		23		23		23		23	23
Viburnum cvs.		12,23	12	23	12,23			23	
Vitis cvs.	9	3	9	3	3,9			3	9

Key to Table 1. Names and addresses of laboratories who submitted information on woody plants.

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5. Evergreen Nursery Co.
   Route 3
   Sturgeon Bay, WI 54235
6. Hartman's
   P.O. Box 90
   Palmdale, FL 33944
7. Hartmann's Plantation, Inc.
   Route 1
   Grand Junction, MI 49056
8. K & M Nursery, Inc.
   P.O. Box 847
   Carpinteria, CA 93013
9. Kelowna Nurseries Ltd.
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12. Herman Losely and Son, Inc.
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13. Dr. Brent H. McCown
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14. Dr. Martin Meyer
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    13557 Portland Rd. N.E.
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16. Mikkelsens, Inc.
    P.O. Box 1536
    Ashtabula, OH 44004
17. Dr. Paul Monette
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18. Monrovia Nursery Co.
    P.O. Box Q
    Azusa, CA 91702
19. Native Plants
    360 Wakara Way
    Salt Lake City, UT 84108
20. Oakdell Nurseries
    P.O. Box 1147
    Apopka, FL 32703
21. Oglesby Nursery, Inc.
    3714 Southwest 52nd Ave.
    Hollywood, FL 33023
22. Phyton Technologies, Inc.
    7327 Oak Ridge Hwy.
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    Hopkinton, MA 01748
27. Weyerhaeuser Company
    Technology Center
    Tacoma, WA 98401
28. Dr. Richard H. Zimmerman
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THE FUTURE USE OF MICROPROPAGATION IN THE UNITED KINGDOM

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There is little doubt that the commercial use of micropropagation has been considerably greater in the United States than in the United Kingdom. Only in the propagation of orchids has the technique become widely adopted in this country.

Since the early 1960's the range of plants which can be successfully micropropagated has increased enormously. While much of the initial activity was centred upon flower and pot plant crops, over the last 10 years there has been more effort directed towards woody plants. Commercial enterprises have been established throughout the world to propagate plants by this technique either in specialist laboratories or on existing nurseries.

What are the advantages of micropropagation?

Rapid propagation — Many systems involve the division of plant material every 4 to 6 weeks, producing, at least, a doubling of plant material on each occasion. In most cases this can continue throughout the year. Large numbers of plants can, therefore, be produced relatively quickly from microcuttings or other parts of plants.

New species and cultivars — These can be introduced into commercial production in large numbers and more quickly than might otherwise be the case.

Disease-free stock — Such stock can be propagated rapidly in a system which helps prevent reinfection and be introduced more quickly than might otherwise occur. Often it is mistakenly assumed, however, that micropropagated material is free from pests and disease simply because it has been through a tissue culture system. This is not necessarily so. It is essential to test material to ensure it is of the required health status.

Propagation of difficult-to-root species — Often such plants can be propagated more readily than by conventional means.

Programmed production — Because the propagation process is highly controlled and can be carried out all year round, production can be accurately planned.

High quality — Quality of plants can be high, especially if selected stock plants are used.

Reduced stock plant area — Because of the ability to produce large numbers of plants the area devoted to stock plants can be much reduced.

Plant export and import — The exchange of material between countries is aided if plants are grown under these clean conditions.

Present use of micropropagation in the United Kingdom.

A range of companies are currently involved in the exploitation of the technique in the UK.

Multinationals — These are generally such companies exploring the possibilities of various areas of plant biotechnology. In micropropagation they tend to be interested in tropical crops or forest tree species.

Specialist micropropagation units — These are set up to provide a service utilising these techniques. Until recently these units have been producing only to contract or firm orders and selling a rooted plantlet unweaned. Recently there has been a trend towards producing a weaned plant in modules, and some laboratories are beginning to produce and sell their own plant lines.

Large nursery companies and co-operatives — There are very few in this category who have provided their own facility.

Specialists nurseries — These produce a narrow range of plants, e.g. rhododendron, choice plants with limited sales or propagation difficulties, and those introducing new species or hybrids. Very few nurseries at present are in this category.

It is difficult to give an exact idea of the crops being propagated at present by tissue culture. Generally pot plants and flower crops would be high on the list in terms of volume produced. A considerable number of disease-free plants such as chrysanthemum and potato are being produced. Plant breeders are using the services of micropropagation firms increasingly either to enhance their breeding programme or to propagate new cultivars. At present the only plant from the range of hardy nursery stock to be propagated in any number in culture within the UK is roses.

Further uses of micropropagation in the United Kingdom.

The area of prediction is beset by difficulties but certain trends are already beginning to emerge. Comments will be restricted to uses of the technique on ornamental nursery stock in the main. Significant uses of micropropagation exist in other sectors of horticulture also.

Multinationals will continue on the fringe but some of their work on forest trees will be of interest within horticulture. Some may take a greater interest in the exploitation of the technique through their subsidiary companies.

The specialist units are already tending to extend their activities and specialise in certain areas and crops. Some will emphasize research and biotechnology while others may well become young plant producers competing with traditional cutting producers.

The large horticultural company or co-operative may well be in some difficulty in the use of this technique. This occurs primarily from the wide range of plants which they grow. Without clear objectives a considerable amount of money and effort could be dissipated to no avail.

Specialist nurseries are in a somewhat easier position in evaluating whether micropropagation is a technique which is useful to them.

Plants which will be micropropagated in the future is again difficult to determine. There has been considerable discussion over recent years of the merits of plants which can be sold in high volume against those with propagation difficulties as suitable candidates for this technique. Personally I favour plants which have or may be capable of large volume sales. If a difficulty in conventional propagation exists which can be overcome by micropropagation so much the better.

The first woody crop plant of major significance to be micropropagated is and will continue to be roses. Within 10 years it is not difficult to imagine half the annual output utilising tissue culture techniques in some way. A major shift towards container roses would probably result rather than direct replacement of the budded field-grown crop. Other marketing opportunities may well develop also.

One other major grouping of plants to be micropropagated will, no doubt, be rhododendron and azaleas, principally due to the success of these in North America. Other ericaceous plants will also be tackled using similar techniques.

Worked trees will not be exempt from the influence of the technique. It will be used to propagate selected rootstocks for some tree species and forms and also to produce trees on their own roots. There could well be some discussion as to whether this will be achieved solely by the use of micropropagation or by the use of improved hardwood cutting techniques. I suspect each technique will find a place in commercial production.

There will be an increasing level of use for micropropagation in the rapid introduction of new material whether with

disease resistance, like the elms, or new cultivars or introductions from botanic gardens in the UK. It should also be pointed out that micropropagation will include both woody plants and herbaceous and aquatic plants.

There is sufficient information available from worldwide research to enable commercial systems of propagation to be developed for a wide range of nursery stock (Table 1). The absence of a species does not necessarily imply any inherent difficulty of micropropagation, but is rather an expression of the vast range of species. Many species will, no doubt, respond to the same or similar *in vitro* conditions as some species already successfully investigated. In order to aid the propagation of such species it should prove possible to group plants according to their general response to *in vitro* conditions. At least three such groupings are emerging and will, hopefully, be refined and developed:

a) herbaceous plants — requiring relatively high nutrients

b) woody plants — requiring relatively low major nutrient concentrations

c) conifers — media has not been accurately determined

Table 1. Successful Micropropagation of Hardy Nursery Stock Species.

Acer platanoides; other *Acer* spp.	*Liquidambar styraciflua*
Alnus incana	*Liriodendron tulipifera*
Azalea (see also rhododendron)	*Magnolia* spp.
Betula pendula	*Malus* spp.
Buddleia davidii	*Paulownia tomentosa*
Camellia spp.	*Phlox* spp.
Clematis spp.	*Pinus ponderosa*
Cornus canadensis	*Pinus taeda*
Cupressus arizonica	*Populus* spp.
Crataegus × *mordenensis* 'Toba'	*Potentilla fruticosa*
Cryptomeria japonica	*Orybys* spp.
Daphne odora, *D. burkwoodii*	*Rhododendron* spp.
Delphinium spp.	*Rosa* cvs.
Embothrium coccineum	*Salix* spp.
Eucalyptus spp.	*Schizophragma* spp.
Forsythia spp.	*Skimmia* spp.
Garrya ellipitica	*Spiraea* spp.
Hamamelis spp.	*Tectona grandis*
Hosta spp.	*Thuja plicata*
Hydrangea spp.	*Tsuga heterophylla*
Hypericum spp.	*Ulmus* spp.
Ilex spp.	*Viburnum* spp.
Kalmia spp.	*Weigela* spp.
Laburnum spp.	

Research aimed at the development of this approach would benefit the industry considerably. In conjunction with this more attention should be paid in research to the effects which *in vitro* conditions can have upon the growth and over-

all performance of plants when potted up or lined out in the field.

Information is deficient at present on the transition of plantlets from culture to establishment in compost and their growth to point of sale. It is hoped that ADAS development work and monitoring will be concentrated upon this particular area as resources allow.

CONCLUSIONS

The preceding comments are hopefully optimistic in outlook and emphasise my belief that micropropagation has a significant place within the UK nursery industry. The technique will not solve all problems (new technology never does) but can be usefully exploited to commercial advantage in many situations. Like any technique of propagation it will have to find its place in the same way as mist or chip budding or hardwood cuttings.

Like so much new technology micropropagation is a very good servant but a dangerous master. One of the major limitations to its successful utilisation is the problem of effective management. It is essential that clear objectives are set for its use on a very narrow range of plants. Once successful this firm base can be used to investigate the feasibility of micropropagating other plants.

WEANING AND GROWING-ON OF MICROPROPAGATED PLANTS

DAVID MILLER

States of Guernsey Horticultural Advisory Service
Guernsey, Channel Islands

The Concise Oxford Dictionary definition of "to-wean" is — teach to feed otherwise than from the breast — by enforced abstinence or counter attractions.

H.J. Welch in his book, "Mist Propagation and Automatic Watering," discusses the weaning problem thus, "I must confess to being skeptical about there being, in fact, any such thing. Even the term "weaning" seems to be singularly inappropriate, the allusion to an infant being gradually taught to accept solid food instead of milk bearing no real connection with what is happening to the rooted cutting.

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some relevance in the case of tissue propagation. "Plants" in culture are incubated in a growth room, where temperature and light levels are closely controlled. Nutrients are provided in the culture medium and a high level of hygiene minimises the risks from injurious pathogens. Not too dissimilar from in a mother's womb I would suggest and feeding at the breast synonymous with a stage of weaning from that highly protected and cossetted environment.

Eventually, usually after a period of multiplication, rooting cultures are initiated. These cultures are kept under conditions very similar to those for multiplication. Normally, within a few weeks, roots develop on the small cuttings and the stage called weaning has arrived. For some subjects, generally for those plants which are difficult to propagate by more traditional methods this can be a particularly difficult phase. However, for the majority of plants, regularly cultured these days, this is not the case. Provided a few basic principles are understood and the correct facilities are provided — plus a bit of common sense — there should not be too much of a problem in weaning tissue-cultured plans.

Admittedly, plants produced in vitro tend to be very "soft" and the transfer from a sterile, non-stressed, fully supporting environment to one where temperature, moisture, and nutrition are constantly changing must be fairly traumatic. The young plants are also highly susceptible to diseases at this stage. Any roots produced are usually fragile and sparse and apparently without root hairs. The young plants do not develop much of a wax layer over the leaves because there is no stress in the *in vitro* environment. Additional wax quickly forms on transplanting though, as do leaf hairs which also tend to be sparse or absent initially.

Some propagators root their tissue cuttings out of culture but the same conditions, possibly even more sensitively regulated than for a rooted propagule, are required. In addition, there is the lengthy rooting period to contend with before weaning can commence in earnest.

Generally the most critical weaning period is over the first few days or so. Humidity is particularly important. So, too, are temperatures and light. Excessive watering should be avoided. *Botrytis* tends to be the biggest potential hazard in the early stages of weaning. Levels of hygiene must be high at all times.

The stage, or degree, of rooting is, in my opinion, important. For most subjects I prefer the roots to be just emerging and certainly not too long. In most cases the type of substrate selected does not appear to be critical provided it is well-aerated and well-drained. It should have a pH appropriate to

the plant with adequate but not excessive nutrients and be free from harmful organisms.

The type and size of container can have more effect. Within reason, depending on the plant subject, the efficient and economic use of expensive space, the larger the container the more rapid growing and better plant developed. There is, of course, a greater risk of over-watering in the early stages with a relatively large volume of substrate.

Personally I prefer a "closed case", or high humidity created by fogging to that provided by misting. With the latter it is too easy to apply excessive water, and nutrients are leached from the young plants. The facility to shade heavily if necessary is also very important. A fungicidal spray, particularly to combat *Botrytis*, is essential. A regular and thorough cleansing of benches, equipment, etc. between successive batches of plants is also to be recommended.

At our experimental station we use a double-skinned poly tent. The outer skin is milky white in the summer months. A high pressure misting line is provided inside the tent but this is only used during the early stages of weaning if it is felt necessary to top up the humidity. There is provision for additional overhead shading should this be considered necessary. Base warming is provided by under-bench heating and there are 400 watt sodium lamps giving 2500 lumens M^2 for supplementary lighting.

Procedure for weaning micropropagated plants:

1) Acclimatization. If possible the ideal is to remove the lids from the culture containers and then stand the containers in the weaning situation for a few days before transplanting takes place.

2) Remove plants from culture containers. As much agar as possible should be washed from the roots. If too much is left on the plantlets there can be problems with fungal growth. Also hormonal residues can have an effect on plant development. One of the advantages of rooting *ex vitro* is that these problems are more easily avoided.

3) Transfer to an open, well-drained substrate, water in well but not excessively. Before closing the case we treat the young plants with a fungicide using a fairly coarse spray giving sufficient to wet the soil surface and the neck of the plant.

The case is then sealed and not disturbed (unless it is suspected that something is not going quite right) until it is apparent that new root and shoot growth has occurred.

In the summer shading is fairly heavy initially, the amount being reduced as weaning progresses. For most sub-

jects bed temperatures of around 19° to 20°C are maintained and we don't mind if the air temperatures rises into the 30's°C, provided the humidity is high. In the winter (from September to March) supplementary lighting, a minimum of 16 hr up to 24 hr a day, is given.

4) Ventilating the case. This is the most critical period of the weaning process. Air is admitted gradually, increasing the shade if necessary during the first few days. If the substrate appears to be drying then a light watering is given. Subsequent waterings usually contain a feed. A further fungicide spray is given at this stage, too. Gradually the amount of ventilation is increased, humidity and shading reduced. Once the young plants are sufficiently hardened and growing well they are transferred to their growing-on areas. The conditions and treatment subsequently will, of course, be appropriate to the individual crop's needs.

WEANING PLANTS FROM TISSUE CULTURE

GRAHAM SHILLABEER

Neo Plants, Limited
Freckleton, Lancashire

I would like to relate my experiences with the weaning from tissue culture of the following classes of roses: Hybrid Tea, Floribunda, Miniature, and Rugosa, as well as the following herbaceous plants: *Bergenia* (cultivars), *Hosta*, *Linum*, *Potentilla*, *Rodgersia*, and *Dicentra*.

Plants received from the laboratory must be in first class condition, free from infection, all clean with a good root system of even size and ideally be kept in a cool room for two days prior to potting into soil.

Compost should be nice and open — a fairly coarse peat containing sand and grit, or alternatively, 40% perlite. I have been very pleased with roses grown in a compost containing Enmag.

It is essential that compost be well soaked prior to pricking off plants. Two days prior to planting we drench the compost with Cryptonol at 12 fl. oz in 25 gal. water.

ROSES

Containers for roses are AP40's or Propapaks which we find are good, practical modules to use, although we are unable to sterilise them for second time around and have, there-

jects bed temperatures of around 19° to 20°C are maintained and we don't mind if the air temperatures rises into the 30's°C, provided the humidity is high. In the winter (from September to March) supplementary lighting, a minimum of 16 hr up to 24 hr a day, is given.

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fore, been taking a close look at Hassey trays. Rooting in Propapaks seems to occur around the edge, whereas with Hassy trays it appears to be more compact and forms a better module.

When pricking off from tubes into soil, one must not fall into the old nurseryman's trap and plant everything; one must be selective and any tube with slight infection must be destroyed. Most plants produce a complete new root system once inserted in the soil. Trays of plantlets are placed on the usual sand bed, 2 in. deep within a greenhouse and covered with milky polythene.

We try to avoid watering overhead for at least a week after standing down trays and spray twice a week with Rovral overhead — although I question the effect of Rovral on rooting and feel Benlate more beneficial to rooting, although recently we have tried a drench of Cryptonol in preference. It is essential to pick off all dead and diseased foliage weekly. For general pest and disease control, we now use fogging machines.

Roses generally root through after ten days from pricking off. Unless we achieve at least 85% good quality plants we feel we've failed and it is uneconomic. After three weeks roses can be potted into 5 in. pots, again into a good, open compost containing Enmag. It is essential once roses are established in the pot to stop down to one leaf above the soil. To give a good saleable container rose by autumn, it is vital to wean in March/April from the laboratory, the final potting taking place in June/July.

Some rose cultivars like 'Elizabeth of Glamis', 'Orange Sensation' and 'Grandpa Dickson' produce a number of shoots from the base naturally, whereas 'Peace', 'Fragrant Cloud' and 'Wendy Cussons' seem very reluctant to break naturally.

The problem with most hybrid tea and floribunda roses appears to be that once they produce bloom in abundance they become top-heavy and flop, in spite of the fact that they have a great root system. It is vital to stop twice, usually in July and in August.

Unless regular stopping is done, in no way will a rosebush reach a saleable size and standard that is expected by the garden centres of today. Very few cultivars break naturally.

Roses produced from tissue culture and planted in a bed alongside roses produced from budding in the field, during the very bad winter two years ago, survived the winter much better than the field roses, kept their foliage much longer, came into flowering a fortnight earlier in the spring, were free from suckers and disease and by the second year were as big in size as their counterparts.

In most cases roses appear to resist most of the effects of the elements better on their own roots than do cultivars on rootstocks.

HERBACEOUS PLANTS

If the plants selected from the tubs are of good quality, well-rooted, uniform, and not too leggy, they will resist all problems and wean very easily. The biggest problem with herbaceous plants is "damping off".

We first used Jiffy 7's net-covered peatballs for herbaceous plants, but found problems with "damping off", and when plants in this module are potted on they appear to have difficulty in rooting through the net.

Experience has shown that herbaceous plants root very well in Propapaks or AP40's on sand beds in a good open compost without Enmag, although for most of our contract growing we find growers perfer herbaceous plants in 2¼ in. Jiffy Pots, as these provide a better and bigger growing module for transplanting.

With 2¼ in. Jiffy Pots we use a compost which contains up to 40% perlite or Silvaperl to provide good drainage and aeration at all times, because the pot appears to get too wet, causes "damping off", and algae tend to survive. Compost also tends to seal over in these pots if they are dry for long periods.

It was felt that herbaceous plants would be better grown on slatted benches during the spring and summer, but results have shown that plants grow much better on sand beds during the summer months and certainly herbaceous plants do better under capillary watering than overhead watering.

Milky polythene must be removed off plants as soon as they are established (approximately after 7 to 10 days). We use milky polythene to reduce light, as the sand beds are situated in alloy tomato glasshouses where high summer light is a problem.

Herbaceous plants from tissue culture establish much better and quicker out-of-doors, even during inclement weather, as they have a superior root system to those produced by the usual propagation methods. With herbaceous plants from tissue culture it is possible to programme more easily and to crop over a longer flowering season.

MICROPROPAGATION DISCUSSION

A question was asked on whether the amount of hand labour required would be the downfall of micropropagation as a technique unless something could be done to mechanise

operations. The speakers felt the ultimate answer would be to go back to single cell or liquid culture but this was some time in the future. In the short term some effort was needed to study the technique from a horticultural angle and adapt from the research methods; at present the most promising stage for mechanisation was during weaning from culture to the growing medium, using a system such as the NIAE bandolier.

Rhododendron yakusimanum was difficult to micropropagate. The problem was the hairs which made it difficult to clean without damaging the tissue and, if this happened, then the culture died. Young material had few hairs but if it was taken right back to the meristem then it was difficult to get it to respond. If buds are used from hybrids there is a good response, but bud tissue from R. *yakusimanum* itself will die. This seems to be a possible technique for distinguishing the species from the hybrids.

RESULTS OF THE IPPS QUESTIONNAIRE ON THE PROPAGATION OF SOFT AND SEMI-RIPE CUTTINGS

BARRY LOCKWOOD

Avon Woodlands, Limited
Welford Hill, Welford-on-Avon
Stratford-upon-Avon, Warwickshire

At the 1981 G.B. & I. Annual Conference, the topic of "Work Rates" was discussed at considerable length. It was suggested that an attempt be made to determine average commercial rates for a range of key nursery tasks.

Subsequently, in May, 1982 our Vice-President, Michael Dunnett, devised and sent out a questionnaire to selected members of the Society on the subject of "Propagation of Soft and Semi-ripe Cuttings". The instructions were, "to select any one week between 1st June and 30th October 1982, and record the number of cuttings which you take and insert during this period".

A recording sheet was provided for the relevant information, together with the questionnaire to be completed. Eighteen nurseries responded.

QUESTIONNAIRE

The questionnaire asked the following:

1. a) Total number of cuttings taken
   b) Number of workers used

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1. a) Total number of cuttings taken
   b) Number of workers used

c) Number of man-hours used
d) Dates the work was undertaken
e) List of the subjects propagated

2. Quality of facilities available — good; average; poor.

3. Skill of staff carrying out the work — unskilled; skilled, combination of skilled and unskilled.

4. Number of times the cutting material is handled after arriving on the propagation bench.

5. Were the cuttings inserted in containers, or directly into the propagating bench?

RESULTS

From the 18 nurseries which responded to the questionnaire, the number of operatives involved varied from one skilled propagator to a team of 10, including both skilled and unskilled workers. The quantities of cuttings varied from 6,000 to 96,000 — taken from late May to the end of October. The majority of cuttings were of the soft, fairly easily prepared subjects, although a number of nurseries included more difficult subjects, e.g. *Berberis*. Most propagators regarded their facilities as average or good. The cuttings were generally handled two or three times on the propagating bench, although three nurseries managed with only handling once. With the exception of one nursery, all respondents inserted into containers of some description. Two nurseries included the collection of cuttings in their rates. (See Table 1).

Table 1. Propagation work rate questionnaire. Summary of data collected.

Nursery	Facilities *	Recording period, 1982	LABOUR Workers	Skill **	Man-hours	CUTTINGS Number taken	Times handled	Stuck ***
A	A	22/10-26/10	8	C	320	40,000	1	C
B	A	13/9	9	C	351	82,000	2	D
C	B	9/8-13/8	3	C	120	29,000	1	C
D	A	18/10/22/10	4	C	120	19,530	2	C
E	A	1/11/-11/11	2	S	28	7,080	4	C
F	A	21/6-25/6	9	C	169	28,300	3	C
G	B	/8-13/8	8	C	238	40,187	2	C
H	A	13/9-17/9	6	C	174	14,637	2	C
J	A	5/7-8/7	2	C	48	12,960	2	C
K	C	28/6-2/7	2	S	80	6,720	3	C
L	A	19/7-23/7	2	C	65	13,702	2	C
M	A	24/5-29/5	2	C	80	13,535	1	C
N	B	27/9-1/10	4	S	133	13,300	3	C
P	B	5/7-9/7	5	C	160	30,000	2	C
Q	A	16/8-20/8	1.5	S	36	7,600	2	C
R	B	14/6-18/6	10	C	60	50,000	2	C
S	A	7/6-13/6	1	S	23	10,500	2	C
T	C	14/6-18/6	8	S	208	96,000	2	C

* A = Good
B = Average
C = Poor

** S = Skilled
C = Skilled and unskilled

*** Cuttings stuck in
C = Containers
D = Directly into bench

On analysing the results to give the rate of work, it is seen that the number of cuttings per man-hour varies from 84 to 830. A difference of ten-fold! We have tried to identify reasons for this great variation, bearing in mind the number of workers, their skill and facilities available, together with the range of plants propagated. No clear pattern emerges. As we analysed the answers it became evident that more and more questions needed to be answered before any relevant conclusions could be reached. (See Table 2).

Table 2. Propagation work-rate questionnaire. Work rate comparison.

Nursery	Number of cuttings	Number of man-hours	Cuttings/ man-hour	Number of Operatives	Comments
A	40,000	320	125	8	*Berberis*
B	82,000	351	234	9	
C	29,750	120	248	3	
D	19,530	120	163	4	
E	7,080	28	253	2	*Leylandii* Collected material
F	28,300	169	167	9	*Berberis*
G	40,187	238	169	8	*Berberis*
H	14,637	174	84	6	*Berberis*
J	12,960	48	270	2	
K	6,720	80	84	2	
L	13,702	65	211	2	
M	13,535	80	169	2	
N	13,300	133	100	4	Collected material
P	30,000	160	188	5	
Q	7,600	36	211	1.5	
R	50,000	60	833	10	
S	10,500	23	457	1	
T	96,000	208	461	8	

Interesting though the returns are, each and every one needs qualification. One respondent was kind enough to offer a detailed list of subjects propagated, together with quantities and times taken for each subject. This shows a variation from 202 per hour to an amazing 1,925.

I would, therefore, suggest that we now have many more questions than answers and I would now like to put forward a few ideas. Let me first go back to the original motivation for the questionnaire:

1. Establish training standards.

2. To influence training bodies to improve proficiency testing standards.

3. Provide information from which future I.P.P.S. workshops/discussion periods can be developed.

4. Establish reference rates, in order to compare new techniques.

5. Provide a reference standard for member's nurseries.

Table 3. Propagation work rate questionnaire. Work rate comparison on species.

Plant	Cuttings/Hour
Ceratostigma plumbaginoides	1,157
Ceratostigma willmottianum	276
Chaenomeles speciosa 'Umblicata'	274
Cornus alba 'Elegantissima'	392
Coronilla emerus	300
Cotinus coggygria 'Royal Purple'	385
Cytisus purpureus	315
Daphne cneorum	857
Deutzia × *kalmiiflora*	400
Euonymus europaea 'Red Cascade'	367
Euphorbia griffithii	360
Fuchsia magellanica var. *macrostema*	510
Humulus lupulus 'Aureus'	202
Hypericum calycinum	1,035
Jasminum humile f. wallick hianum	440
Lippia citriodora = *Aloysia triphylla*	600
Parrotia persica	240
Philadelphus × *lemoinei* 'Manteau d'Hermine'	516
Philadelphus microphyllus	920
Potentilla fruticosa 'Vilmoriana'	510
Ruta graveolens 'Jackman's Blue'	440
Sambuscus nigra 'Aurea'	250
Viburnum × *bodnantense* 'Dawn'	1,440
Viburnum × *carlcephalum*	278
Viburnum carlesii	280
Viburnum farreri	429
Viburnum farreri 'Nanum'	450
Viburnum plicatum 'Lanarth'	1,266
Viburnum plicatum forma *tomentosum*	1,200
Viburnum plicatum forma *tomentosum* 'Mariesii'	1,283
Viburnum opulus 'Sterile' = *V. opulus* 'Roseum'	1,925
Viburnum opulus 'Notcutts Variety'	1,500

Note: *Rates vary by up to 950%.*

CONCLUSIONS

It is clear each nursery has its own unique facilities and staff. However, there are many areas where techniques could be standardised and useful comparison made.

a) Composts — variable constituents — degree of compaction; sandwich layers, e.g., *Clematis*

b) Containers — depth of tray — dimensions — weight

c) How cuttings are collected — trimmed individually, or whole branches

d) Maturity of cuttings, and their turgidity for leaf removal

e) Necessity of leaf removal — last year's project prize winner

f) Use and type of rooting hormones and auxins — powder or liquid formulation

g) Wounding, or shoot tip removal

h) Presence of spines, e.g., *Berberis*

i) Most useful tools — knives, secateurs, scissors

j) Quality selection of material

These are areas which require definition and — most important of all — DO THEY ROOT!

I believe there is a great necessity for basic knowledge on the fundamentals listed above to be set down in some agreed format. My suggestion would be to follow the precedent already set by the British Container Growers Group, in trying to tackle the specification of standards for container-grown plants.

It would be a long but very worthwhile job. Take a typical subject from each species, and try to clearly specify the requirements under the following headings:

1. Time of year
2. Length and type of cutting — number of leaves
3. Treatment of cutting — tipping — leaf removal — wounding
4. Specify compost, and its physical state
5. Specify rooting hormone/ fungicide
6. Type of container
7. Spacing of cutting
8. Labelling
9. Use of cool rooms
10. Layout of work areas

My proposal would be to take, say, ten subjects, representative of a number of genera in common production and specify, if possible by general agreement, the criteria for the preparation and insertion of these subjects.

During the discussion which followed, a request was made for the committee to undertake another survey to obtain definitive rates which could be disseminated to the ATB, ADAS, and the industry. More members should be invited to participate. There was a need to specify subjects and limit species to get some basic information first. Outside bodies with expertise in devising surveys should be approached, as well as contact to be made with ADAS or other bodies with specialist work-study knowledge.

"HOW IT IS DONE" — THE COMPANY THAT PRODUCED THE BEST RESULTS IN RESPONSE TO THE G.B. & I. IPPS QUESTIONNAIRE

DOUGLAS ANDERSON

Darby Nursery Stock, Ltd.
Methwold Hythe, Thetford, Norfolk

The following is an outline of the methods we use in cutting preparation and in insertion of the cuttings. We have no special facilities available for this operation. In common with other nurseries, benches have been accommodated in existing buildings and the operation has had to fit into the existing layout.

To complete the I.P.P.S. questionnaire we recorded cuttings prepared and inserted during the third week in June, as shown in Table 1. These were all softwood cuttings of deciduous shrubs such as *Buddleia*, *Chaenomeles*, *Fuchsia*, etc. Twenty percent were inserted in paper pots, the remainder directly in trays.

Table 1. A record of cutting propagation during the third week of June, 1982.

Date	Number of workers	Number of hours worked	Total hours	Total cuttings prepared and inserted
14/6	8	4	32	13,200
15/6	8	6	48	22,300
16/6	8	6	48	22,300
17/6	8	6	48	20,100
18/6	7	6	42	18,100
			218	96,000
Less 9¾ hours for 10 min breaks:			9¾	
			208¼	

Approximately 461 cuttings were prepared and inserted per worker-hour.

Staff: All staff involved in cutting preparation are females and work as a team of eight. The team is made up as follows:

4 — Grading and trimming cuttings and applying rooting hormone via a soaked sponge.

1 — Inserting cuttings.

1 — Grading and trimming cuttings or inserting as required.

1 — Labelling, recording, transporting trays of cuttings to the propagation houses.

1 — Preparing and filling trays with pre-mixed compost, transporting trays of cuttings to the propagation houses. Can be used to insert cuttings if required.

The team has been working together for at least ten years, and are highly skilled. They organize their own work and interchange if necessary. The work is carried out on a piecework basis at a current rate of 25½p or 28½p per tray — each tray contains 72 cuttings. The differential in rate allows for the relative difficulties encountered among species. Farm labour in East Anglia has a tradition of working on a piecework basis.

Operation:

1. Cutting material is gathered from a stockbed and placed in a cold store where it is held for at least 24 hrs but not more than 48 hrs.

2. Cutting material is taken from cold store and placed on cutting preparation table.

3. Cuttings are sorted, graded, trimmed, and dipped in a hormone solution then placed in trays.

4. Trays of prepared cuttings are passed to person responsible for insertion.

5. Compost is prepared in an Adelphi mixer and conveyed to end of potting bench.

6. Trays are filled and taken to cutting preparation area on a hand trolley.

7. Cuttings are inserted and trays of cuttings replaced on trolley.

8. Trays are labelled with cultivar name and date of insertion. Numbers are recorded in stock book.

9. Finished trays are transported to the propagation house.

HOW CAN IPPS HELP IN FUTURE PROPAGATION TRAINING?

THOMAS J. CAMPBELL

Agricultural Training Board
Bourne House, Beckenham Road
Beckenham, Kent

I will concentrate on two areas: one is in continuation of the immediately preceding sessions on work rates and standards, and the other is on the future relationship of IPPS to the provision of industrial training in the nursery stock and related interest sectors of horticulture.

To ensure that we all have the same understanding, my definition of "work rates" and "standard rates" are:

The team has been working together for at least ten years, and are highly skilled. They organize their own work and interchange if necessary. The work is carried out on a piecework basis at a current rate of 25½p or 28½p per tray — each tray contains 72 cuttings. The differential in rate allows for the relative difficulties encountered among species. Farm labour in East Anglia has a tradition of working on a piecework basis.

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To ensure that we all have the same understanding, my definition of "work rates" and "standard rates" are:

Work rate — *is an assessment of the effective speed over a* short time period and takes no account of rest time or other factors,

Standard rate — is the average rate at which qualified workers will naturally work at a job, provided they know and adhere to the specified method, and provided they are motivated to apply themselves to their work.

In the context of our work in the Agricultural Training Board, I prefer to speak of achievable standards of performance and would ask you to bear in mind that such achievable and consistent standards can only be attained by effective work *planning and skills training. You must ensure the work place* lay-out is the most satisfactory within the limits or constraints of the business, i.e. the placement of benches or work surfaces, the siting and arrangement of plant materials, composts, containers, trays, rollers, or trolleys and the positioning of the worker in relation to the job. Account must also be taken of the nature, condition, and characteristics of the materials (conifers/*Berberis*/*Erica*), rigid, semi-rigid, or polythene pots, etc. the suitability of the compost, and the environment in which the worker operates.

The labour force must be trained in the specific work activities related to each job, not just shown how to do it and left to get on with it.

In work recently carried out by the Agricultural Development and Advisory Service on the preparation of cuttings and hand potting techniques, they so rightly qualify performance standards in 3 distinct categories:

Good — The output of a well-trained worker in good work conditions working with first class materials in a well laid out work place.

Typical — The output of the average worker in average conditions.

Poor — Least skilled workers operating under poor conditions.

Table 1 gives an example of an achievable standard of performance after training:

Table 1. Potting. Approximate throughput rate per person per hour.

	Old Method (Hand)			New Method (Hand)		
Crop	Good	Typical	Poor	Good	Typical	Poor
Rooted cuttings of *Hedera* placed into 9 cm pots	450	250	150	840	570	330

It is, perhaps, interesting to note that the comparative output from a potting machine per person per hour was:

Good	Typical	Poor
800	600	370

These potting machine figures per person are based on a team of 4 workers.

Training in the precise method and sequences of activities related to the performance of a specific task is essential if the worker is expected to emulate the through-put achieved as the result of a method studied project. I urge you — do not make the mistake of expecting a poorly trained, poorly motivated person working with mediocre plant material in badly lit, draughty, uncomfortable work conditions to equal the performance standards displayed in the demonstration area and then fault them for not doing so. This may seem gratuitous advice, regrettably it is based on experience.

How many times have new techniques floundered or somehow never achieved their promise? Possibly because the views and comments of the work-force were neither sought nor considered when the changes were introduced, neither were they trained in the job method and the essential work skills of the new technology.

In the wider context of industrial training, I believe that members of I.P.P.S. are ideally suited and able to share their skills and expertise with others. Indeed, is not your motto, "To seek and to share?".

To Seek: Is to assist in the identification, development, and validation of new propagation and production techniques;

To identify specific subjects or production processes which could lend themselves to research and development projects;

To identify areas in the work cycle of established propagation techniques which are of particular learning difficulty; and

To identify and agree on standard work methods which could lead to the establishment of standard performance rates.

To Share: By working in cooperation with the education and industrial training services to stimulate interest in career development and progression through relevant further education and work skills training;

By assisting in the preparation of training programmes designed to overcome the problems of particular learning difficulties;

By becoming instructors in specific work skills and particularly in the new techniques of nursery stock propagation; and

By stimulating interest among fellow members in the benefits of instructional techniques training both in their own work and when passing on their skills to others, and the benefits to the business as a whole of training in work organisation (studying the method of the job, work planning, and work place lay-out).

Finally, "seeking and sharing" by continuously striving to ensure ever more credible and acceptable proficiency tests by working with the testing service as skills examiners and assisting in the development of standard work systems and techniques, and identifying and agreeing achievable standards of performance. To conclude in the vernacular of this city:

"Lang may ye seek and share".

THE PRODUCTION OF POT-GROWN LINERS IN FRANCE

ANDRE BRIANT

Briant Pepiniere, BP 15, St. Barthelemy, D'Anjou, 49800 Trelaze, France

The story of a pot liner starts either with a seed, a cutting, or a graft; let us start it with cuttings.

The cutting material is collected from the stock plants each morning while it is still cool. Then it is kept in cold storage until the cuttings are made (never more than 2 days). All the cuttings are made with secateurs. The speed depends on the worker, of course, but mainly on the species, and it can vary from 200 to 500 per hour. Cuttings are dipped in hormones; we use IBA at concentrations between 1 and 5 parts per 1000.

Polythene tunnels are used for propagation. These are 8 metres wide and 30 metres long, double skinned with windows for ventilation. They are whitened for protection against the sun; we do not use any other shading system. The cuttings are stuck either in frames or in multipots. In both cases the compost used is a 50/50 mixture of peat and sand.

During the first three weeks humidity is kept as high as possible (around 97%) either with mist, with "Humid Air" — which is very close to a fog system — or with a low level tunnel. Then when roots appear, vents are gradually opened.

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Cuttings made between June and October are potted the following spring. During this period they are protected from pests and diseases. Very few tunnels are heated during the winter.

Rooting success varies considerably according to the species and cultivar and can range from 20 to 100%. Overall we use about 75% of the cuttings we make.

The breakdown of labour costs to produce a rooted cutting is as follows:

Care of stock plant, 4%	Sticking cuttings, 16%
Collection of cuttings, 10	Care while rooting, 5
Preparing cuttings, 6	Lifting of cuttings, 3

(Two workers collect cutting material for 10 to 13 propagators)

Potting. As mentioned earlier, most of the softwood cuttings are potted between March and June. Most of the conifers are potted in September and October. We use a German Plantarex potting machine. We think it is the most efficient for bare-rooted cuttings but may be a little slow. Since we are moving towards the use of more multipots, we think that in the near future we will be able to use more sophisticated machinery and so speed up the process of potting.

We generally have six people working two machines. One supplies compost, two are potting, two are supplying pots and putting into trays, and one transports the pallet to the tunnels. The compost operator also carries trays from the rollers to the pallets. In total they pot about 18,000 plants in an 8-hour day, i.e. 3000 per person.

Polystyrene trays are used containing thirty-five 8 cm pots. The pots are spaced 10 cm apart to encourage a bushy plant habit. We find that if plants are placed too close they become too thin.

The compost is made up of 40% fine bark, 30% very fine bark, and 30% peat. An 8 to 9 month formulation of Osmocote is added at a rate of 3kg/m^3. The bark, which is generally pine, is not composted but used immediately after delivery.

After potting, the young plants remain 3 to 4 weeks in tunnels until they have rooted around the pot then they are moved outside. The quality of the liner will depend on the aftercare we provide — irrigation, weeding, feeding, spraying, and trimming.

Irrigation. Water is given through oscillating spray lines which are portable. They are programmed to operate twice daily, from 6 a.m. in the morning and from 4 p.m. each evening. The amount applied, 3 to 5 mm each session, is decided by the foreman in charge. There is no hygrometer.

Feeding. Initially, the Osmocote in the compost provides adequate nutrition, but from early June liquid feeding is given via the irrigation system. We start from a concentrated solution which is injected in impulses into the pipes and diluted at 3 parts per 1000. The stock solution is adjusted according to the analysis of the water. The interesting thing about this system is that we can use any type of water; the pH is lowered with nitric acid. We generally cease feeding at the end of August to allow the plants to harden before winter.

Weeding. The weed problems are reduced by the use of our sterile compost. Herbicides we use are Simazine at ½ kg per hectare, Tenoran at 3½ kg per hectare, and Ronstar 2G (granular form) at 120 kg per hectare. In the last two years we have tried a new chemical called Boulherb, which is a mixture of lenacil and neburon. Used at a rate of 7 kg per hectare it lasts two months, and seems to be an efficient chemical. Most plants have tolerated it quite well up to now. An important aspect with herbicides is the method of application. To be effective it must be done very carefully. Overdosing causes accidents; too little avoids accidents but gives poor weed control. We spray with a boom which is the same width as the beds (3 m); the rate of application is controlled by the walking pace of the two operators at either side. The pressure is constant. For the last two years hand weeding has been reduced to 1 minute per 400 pots for the whole season.

Spraying. Pests and diseases are a constant problem so we spray all plants at 3-weekly intervals with a fungicide and insecticide. We use alternately Benlate, Aliette, Thiram, Captan, Decis, and Kilval.

In addition, plants are shaded, pruned and staked to make them saleable by the end of September.

THE PRODUCTION OF POT-GROWN LINERS IN DEVON

NIGEL JOHN TIMPSON
Hewton Trees and Shrubs
Bere Alston, Devon

The nursery at Hewton was established 14 years ago. Since I took over in 1976 we have considerably expanded the facilities and production output. On the 3½ hectare nursery, 1½ hectares are used for production and 2 for stock planting. Most of our facilities are under polythene and we have space for ½ million plants under cover. Our current production is

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around 700,000 plants per annum, 90% of which are produced from cuttings; the remainder, apart from about 5,000 grafts, are from seed.

We specialise in liner production and are, therefore, able to give the attention to detail that is required to enable us to successfully propagate difficult plants. Our policy has always been to concentrate on propagating plants which other people find difficult, or which are in demand for some other reasons — perhaps there is a shortage of suitable stock material for propagation. Growing difficult plants has stood us in good stead in years when orders have been difficult to come by.

When people visit the nursery they often say how favoured we are in Devon since we have such a good climate with practically no frost. This is not really true. Although our average temperatures are higher than in many parts of the country, we must have had 12 to 15 nights last winter when the temperature reached −4°C or lower. However, the most significant weather factor is our relatively high rainfall, over 1000 mm a year; this makes it difficult to over-winter small plants outside.

Having said that we do not have a particularly good climate, I believe we do have certain natural advantages. Firstly, we are situated on the banks of the River Tamar which is up to 300 m wide at this point. The reflection from the water, or mud as it is at low tide, seems to give us very high light levels even on a relatively dull day. Secondly, we have a very good clean water supply from Dartmoor. This comes from a granite area and the pH is quite suitable for the sort of plants we grow. It means that we have no deposits on our cuttings even after a long period under mist and that a blocked mist nozzle is a rare occurrence. The third asset which we have is the availability of the well-known Cornish grit. Our grit actually comes from Devon from the china clay workings north of Plymouth. These three advantages, plus reasonable facilities, combined with our experience, mean that we are more successful than many nurseries with the propagation of difficult plants from cuttings.

We use several different facilities for our propagation. For instance, we use unheated frames for early cutting of dwarf rhododendrons, the frames being covered with Dutch lights and shaded as necessary. However, the bulk of our propagation is carried out using mist under glass or polythene. In our main propagation house we have benches fitted with heating cables and mist facilities. The house is completely unshaded to allow maximum light levels; this causes no problems and, indeed, is essential for successful propagation of many decidu-

ous species such as magnolias, parrotias and azaleas. For artificial lighting we have fluorescent tubes fitted which are used to extend daylight on these deciduous cuttings from dusk until about 11 p.m. These will be used from the end of the first week in August until early November. In this way we are able to get sufficient growth and root establishment on otherwise difficult plants to enable them to over-winter successfully.

Apart from one trial solar control unit, we are using wet leaves to control the mist operation. We have found the solar control to be more satisfactory and, in due course, I expect to convert all our mist to this type of operation. We use the mist as little as possible, and from October until March on most days it will be manually controlled. On many days during the winter it will only be used for two or three short mistings. This has the dual advantage of keeping the cuttings dry and thereby requiring less bottom heat. For summer propagation we maintain a minimum of 20°C bottom heat, but for most species this is progressively reduced during the autumn and during the coldest weather in December and January, may be as low as 12° to 13°C. There are some exceptions; for instance, *Magnolia grandiflora* cultivars require around 18°C to enable them to callus, and hardwood cuttings of vines and figs will tend to rot if the bottom heat is below this figure.

Most of our propagation is done in trays with a depth of 2½ in. but for some species such as magnolias with large root systems, we use 3 in. deep trays. Some plants, which do not tolerate root disturbance, are propagated in individual pots; for example: *Vitis*, *Fremontodendron* and *Embothrium*.

We use a 3:1 sand/peat mixture for much of our propagation but for many species which are susceptible to decay or are otherwise difficult, we use pure sand. These include, for example, *Garrya*, *Daphne*, and *Ceanothus*. All our cuttings are wounded when they are prepared and we use Seradix 2 or 3 mixed with various proportions of Captan. During their time in propagation cuttings are regularly fed with a weak solution of Bio Number 5.

As propagators specialising in difficult to root plants, we have to be more successful than the next person. A combination of the techniques previously outlined plus attention to detail, particularly in relation to hygiene enables us to achieve good rooting percentages.

We also propagate during late summer and winter under polythene tunnels, 58 ft long by 14 ft wide and 6½ ft high. The environment in the tunnels is not suitable for all plants; for instance, garryas and daphnes we would only propagate under glass.

In one of these tunnels we have heating cables with a misting system. This works well but is expensive to run since it is not properly insulated. A further five tunnels are used for winter propagation, this time on benches which have warm air ducted underneath them. This system works extremely well and even in the coldest weather we are able to maintain a bottom heat of 10° to 12°C at night — sufficient for propagation of many species. There are lights available in two of these tunnels so that we can keep plants or rooted cuttings growing during the autumn period if this is required.

Following rooting, cuttings are held in tunnels prior to potting. Having tried carefully controlled machine potting we have for several reasons returned to potting everything by hand. We can achieve a much more uniform product in terms of depth of potting, centralisation in the pots, and degree of firmness of the compost, the latter being particularly important when trying to establish a batch of difficult plants. In addition, we find that we can achieve a higher output by hand, although there is still room for improvement, perhaps by incorporation of some of the features of the ADAS hand potting method. Potting starts in the middle of February and continues until the end of summer.

The most difficult aspect of our production process is the establishment of the young plants after potting. To ensure continuity one person is solely responsible, apart from weekend cover, for watering and looking after plants in the tunnels. She has no other responsibilities so can devote all her time to this without distraction and give the attention to detail which is so important. It is not sufficient to turn on a spray line to water batches of difficult plants, so a lot of our watering is done by hand, with the sprinklers being available as a backup in hot weather. Where difficult plants are being grown in large numbers I regard establishing and looking after them as being the most demanding job on the nursery. Propagation becomes relatively simple once the techniques have been worked out, whereas the factors affecting young plants vary all the time.

Our principal pest problems are red spider, aphids, and tortrix caterpillars. These are controlled by two or three overall sprays during the season with spot treatment where there is a particular problem.

Weed control is all by hand. Where chemical methods have been tried, for instance Ronstar granules, we have experienced an unacceptable level of damage to freshly potted plants. Our main problem, accentuated by our lime-free water, is liverworts and this we live with until it reaches an unacceptable level, when it is controlled by top dressing the pots.

The final part of our production process is the selecting of the plants for despatch. We always aim to provide plants which have been carefully graded, so that our customers will be able to produce an even batch of container plants.

Looking to the future, I have been keeping a close watch on developments in the micropropagation field. I have considered the setting up of a small unit but have now decided that the way forward for us is to take micropropagated plants from an existing unit and establish them in small pots — a process which we should have the right techniques to do successfully. During the next 6 to 12 months we shall be gaining some experience in this field so that we will be in a position to take advantage of future developments.

Finally, I would like to comment on the position of the liner producer in the industry today. It seems to me that the future is very promising, certainly where more difficult plants are concerned. A container grower wishing to produce 200 saleable plants of a species such as *Magnolia grandiflora* may need to start with twice as many cuttings to enable him to produce a well graded batch of plants for potting on. The liner producer, on the other hand, will be able to give the attention to detail which is required to obtain 90% of the plants suitable for potting on. This same argument applies to many plants and I believe that, for economic reasons, the trend should be to more specialisation of production, with liner producers and container growers concentrating on what they are able to do well.

DIRECT ROOTING OF DORMANT CUTTINGS

CHARLES H. PARKERSON

Lancaster Farms, Inc.
5800 Knotts Neck Road
Suffolk, Virginia 23435

For many years we have used the procedure of taking cuttings and sticking them directly in a pot filled with growing medium. The cuttings then root and continue to develop into mature liners without interruption until harvest.

The basic system of direct rooting and procedures for handling cuttings is explained in detail by Sidney B. Meadows (1) in a paper presented to the IPPS Southern Region in 1981.

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Usually cuttings are made during the summer months using multiple cuttings per pot. Nicely-rooted liners are ready in September and on occasion we get a fall flush of growth. Liners are overwintered in unheated poly-houses until March, at which time unit heaters are installed to protect the new spring flush of growth. Planting into #2 or #3 cans starts after the first full moon in April, which is traditionally the last frost date in our area. Plants are grown can-tight for one year, then spaced and marketed beginning in June until they are all sold.

We observed on many occasions that plants developing from a liner that had received a fall flush of growth were consistently larger. Since we sell by plant size and grade it was to our benefit to try and take advantage of this observed increase in growth. In addition, we have noticed that the first spring growth made by field plants is the strongest and best top growth we have all year. Something good is stored in the plant just waiting to explode in the spring.

Our first attempt for increased growth in our liners is outlined in our paper, "Cold Storage Treatment of Cuttings" (2), presented at the IPPS Southern Region meeting in 1980.

The following procedure has been used for the past two years with excellent results on a wide range of broadleaf and coniferous evergreen plants.

One propagation mix that works well for us is:

5 parts pine bark
1 part peat moss
3 parts horticultural perlite (coarse)
8 lb./cu. yd. Osmocote (18-6-12)
1 lb./cu. yd. Micromax (slow-release micronutrient)

These are blended together in a 6 cu yd cement mixer until well mixed then screened. A plastic 18 × 18 in. tray is filled with square 3-in. pots. This unit of 36 pots is run through a tray filler and then set on ground beds of #5 crushed stone in a poly-house.

Mist is suppled by rotary type nozzles, either a Buckner #1124-4 at a spacing of 9 × 16 ft or a Ross #244 spaced at 15 × 20 ft. Both nozzles have proved satisfactory but not perfect — too much water during propagation and too little during liner growth period — but they provide a happy medium that we can manage.

Cuttings should be made before the second week of April, which is prior to growth in the field. We try to start as soon as the propagation house become available. Cuttings are cut, dipped in an IBA solution, and stuck. The cuttings are not stripped of their lower leaves.

When we first tried this procedure we did not know what to expect — 1) root then grow? 2) grow then root? 3) die? 4) root then not grow? 5) have poor growth? etc. I am convinced that the physiological condition of the cutting at the time of making can be the cause of all of these expected results. If top growth of the plant has started when the cutting is collected then, in general, we get results less than desired, i.e. rooting is very slow and weak and top growth is poor.

The ideal cutting has good caliper and is taken before new leaves form. This cutting will root without hesitation and then produce in short order a very strong top flush of growth. Subsequent growth cycles are regular during the summer following propagation. One word of caution — to maintain quality and prevent leggy plants, attention must be given to pruning. So far this summer we have tipped our liners four times.

We believe that a decided advantage has been gained by taking early cuttings. This procedure will be a standard practice in future propagation procedures for most broadleaf plant material we produce.

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PRODUCTION OF POT-GROWN LINERS USING THE "LEVINGTON TRAY"

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Abstract. Traditional methods of growing-on rooted cuttings in 7 or 9 cm pots (pot grown liners) commonly consist of standing the pots in small open mesh trays or similar carriers. These methods are often expensive in handling costs, apart from the difficulty of applying water evenly and avoiding attacks by soil-borne diseases. The use of an isolated pallet handling system ("Levington Tray") eliminates these problems and thus produces a higher percentage of good standard pot-grown liners. Additionally the "Levington Tray", holding 294 × 9 cm or 442 × 7 cm pots allows for mechanical and lower handling costs from potting up the rooted cutting until it is returned for potting in the final container.

INTRODUCTION

Standing down trays of pot-grown liners and later picking them up for transfer to the potting machine is a tedious, backaching job for the operator and an expensive handling exercise for the employer. Additionally, it often proves difficult to water the small pots evenly which either results in the plants on the edges suffering from drought or, conversely, if the trays are stood on polythene, of some plants suffering from standing in puddles of water. In many instances, even if the pots are isolated from the ground with a layer of polythene, the area is walked on so extensively that it is difficult to ensure complete freedom from soil-borne diseases. Therefore, at Fisons Nurseries a system was looked for which would meet the following needs:

— Evenness and ease of watering or feeding.

— Cleanliness and isolation to give disease prevention.

— Easy, low cost handling to allow optimum use to be made of the various growing environments available on the nursery.

— Easy management that would allow for the use of less skilled people.

It is believed that the use of the "Levington Tray" meets the above objectives and offers the opportunity to standardise and improve the production methods of pot grown liners.

To date the above programme has kept the propagation house free of algae and any obvious signs of the usual diseases expected, particularly *Rhizoctonia*, *Fusarium*, *Botrytis* or *Phytophthora*.

Pot-Grown Liner Production. Pot-grown liners (liners) on the nursery are produced in two basic sizes of pots, these being 9 cm for conifers and 7 cm for mixed shrubs. Fisons Container Compost is used throughout with the Ficote addition being used for early/mid-summer potting.

At first the liners were placed in Empot Trays which, in turn, were stood on the floor of the house which had previously been covered with a porous woven polypropylene fabric (Mypex), the pots being watered by an overhead sprayline. This produced reasonable results and avoided puddling, but it did not provide sufficient isolation from the soil.

The next step was to place the liners, still in Empot trays, on polythene covered pallets, again with watering via an overhead spray line. This provided isolation, overcame puddling, but did not overcome watering problems or excessive handling — Empot trays not travelling down the roller conveyors in use on the nursery. Therefore, it was decided to see if traditional methods could be dispensed with. The result of this thinking is the production of a palletised handling system, or the "Levington Tray".

METHODS

Propagation. Growing clean plants begins at the cutting stage, and every effort is made right from the start to produce clean, healthy, and vigorous plants. Cutting material is taken from disease-free plants and all cutting preparation is carried out under clean conditions.

Propagation is on sub-heated mist sand beds, each bed of a size which avoids the need to step onto them. Propagation trays are plastic with a mesh base. The compost used is peat-based with perlite or grit added to ensure that the drainage characteristics are adequate to cope with the amounts of water applied via the mist nozzles. Disease prevention during the propagation stage is as follows:

— the mist beds and cutting trays between crops are drenched with a chlorine solution using Fi-Tab R/D tablets (sodium dichloroisocynurate) at 4 tablets per 100 litres to give 100 mg/l chlorine concentration.

— the mist beds are not walked on.

— the cutting material, on arrival from the field, is washed in Captan before preparation and then inserted into the compost which has received a prior watering with Filex (propamocarb hydrochloride). Thereafter, the cuttings are sprayed at two-week intervals with either Rovral (iprodone) or Benlate (benomyl).

The 'Levington Tray'. The first step in the development was to establish what was required from the system. The requirements considered of priority were: isolation from soil contamination including that from shoes; ease of sterilisation between crops; simple and even water application; movement of an economic load; fitting the standard trollies in use on the nursery; be able to pass through all tunnel or shade house doors; be comparable in cost with plastic trays holding a similar amount of plants; and finally, if necessary, be light enough to be lifted manually.

Timber was chosen for the construction due to the cost of approximately £15 per tray using treated wood, plus the fact that timber allows the trays to be repaired on site. The "trays" are constructed using 4 × 5 sq. cm longitudinal bearers fastened to 3 × (7.5 cm × 4.4 cm) cross supports. An edge board 12.5 cm by 1.8 cm is then fastened all round to give an effective pot standing depth of 6.25 cm. The "floor" of the "tray" is 1.25 cm plywood. The whole of the interior is then lined with polythene on which is placed a capillary mat.

The "trays" will hold 442 × 7 cm or 294 × 9 cm square pots. The weight of an empty tray is approximately 42 kg, or 100 kg if filled with pots using a peat compost.

Irrigation of the trays is via a Cameron trickle system. A plastic elbow joint is placed in one end of the tray to provide drainage in case of excessive rainfall, or to control the level of water within the tray. In practice it is beneficial to place the trays so as to provide a slight fall towards the drainage point and away from the trickle nozzles.

The disease prevention programme started in the propagation stage is continued throughout the pot-grown liner stage as follows:

— Complete isolation for surrounding soil, which includes the absence of any "dirty boots".

— New pots used for each crop.

— Between crops, new polythene is used to line the trays, and capillary mats are either new or sterilised.

— Alliette (ethyl phosphate) is applied to all the pot-grown liners at potting, six weeks later, and immediately prior to potting in the final container.

— The basic pest control programme consists of Basudin 5G Granules (diazinon) sprinkled on the capillary mat against Sciarid fly, and the incorporation of Aldrin or a drench by Aldrex as a precaution against vine weevil or leather jackets.

CONCLUSIONS

"Levington Trays" have been used for two years for growing a wide range of shrub and conifer species. The use of the "trays" is meeting all the objectives aimed for, i.e.

— easy, low cost handling, which means that short periods under cover after potting to get the roots moving and before standing outside become feasible;

— even watering to each pot becomes a reality, removing losses due to localised drought;

— complete isolation and protection from the soil and soil-borne diseases; and

— good management is possible with less skilled staff.

These all combine to assist in the production of a good, healthy, vigorous standard product by standardised methods at an economic cost.

POT-GROWN LINER PRODUCTION IN DENMARK

ANTON THOMSEN

Thomsens Plantskole
Skalborg, pr Aalborg, Denmark

If I look back to 16 years ago most conifer production in Denmark consisted of striking cuttings in frames where they remained for two years, followed by two years set out in well prepared beds before being planted out in the field. Today, approximately 80% of the conifer liners are produced by four nurseries, on a similar but not identical method to the one we use, which I will describe.

In 1967 we built two aluminum greenhouses 20 × 61 m to rationalise production of liners. Half of one house was equipped with mist propagation, the remainder of the glasshouse area was used for winter potting of rooted cuttings. This was to produce better liners and make good use of labour in the winter. Today we have four greenhouses of this size, using one for propagation and the others for potted liners.

Our present production of liners is outlined. From July to October *Juniperus*, *Chamaecyparis*, some *Thuja* and *Berberis*, *Euonymus fortunei*, *Skimmia*, and *Ilex* cuttings are struck in flats, using a medium of peat and styrofoam balls. From the end of January until mid-March they are potted in rigid plastic pots, using a potting machine. From the end of May to mid-June the liners are moved from the greenhouse to outdoor frames.

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Taxus are struck from mid-September and have to be finished by Christmas, beginning with *Taxus baccata* cultivars and finishing with *Taxus* × *media* 'Farmen'. Cuttings of most *Thuja occidentalis* cultivars are taken from mid-February until April, when we again have empty space in the propagation unit. These plants will be well-rooted by May and are potted in the empty greenhouses in July and moved outside in November or December, covered with white plastic to shade and protect them from frost and wind. In our area the temperature will be down to −30°C in some years, and generally down to −20°C for at least a few days, often with no snow cover on the plants. Because Denmark is surrounded by sea the weather changes frequently, so that in one month we might range from −25°C with snow to 10°C with rain. This makes it very difficult to take the right precautions.

Picea abies cultivars and *Picea glauca* 'Conica' cuttings are the only cuttings struck outside. They are struck in June under plastic tunnels with mistlines and left a year before potting in 10 cm pots outdoors. After a further year they make beautiful 15/20/25 cm plants by July or August. If numbers are short, they can be potted in January under glass and will produce a fairly good 12/18 cm plant by June.

Slow-growing *Cotoneaster* 'Cotali', *C. cochleatus* 'Taja', etc., *Hypericum calycinum*, *Pachysandra terminalis* 'Green Carpet', *Vinca minor*, and other ground cover plants are struck directly in 9 or 10 cm pots under polythene tunnels or in greenhouses. We expect to produce 75 to 90% saleable plants and, if a species does not do well in our standard compost, we do not grow it.

All liners are potted in 9 or 10 cm rigid plastic pots, using the following compost mix: 20% fumigated clay soil, 20% rockwool, and 60% good quality peat, with 1¼ kg NPK and ¼ kg lime/m^3. All watering is automatic and we are using liquid fertilizer (the Hornum mix) and occasionally extra potash and nitrogen. Only overhead watering is used, but as pots are stood on 2 cm sand over polythene, there is some capillary watering effect as well.

We know that this system of producing liners doubles the workload of moving the plants, but we feel that the faster liner production and evening out of labour peaks repays the extra expense. However, I must admit that the higher oil prices we have to pay because of the high dollar rate make it more difficult to recover the extra costs.

The liners are kept clean with the use of Simazine and Tenoran plus a little handweeding. Diseases are controlled

with sprays of Zineb and Maneb or Benlate at three week intervals from about the middle of July.

For transport we use homemade lightweight trolleys with linked wheel axles which trail further trolleys in their tracks, thus saving space at the end of beds. In the greenhouse we always fill the last metre by the middle aisle with a fast growing plant which can be potted last and moved out first, which makes use of all the available space. The liners are moved out by means of tractor and trailers. For internal transport I had an engineer design a container with shelving to carry liners in 40 × 60 cm plastic flats. This container fits onto a Europallet and can be carried by two men when empty. It is made of very light steel which our men make during the winter. Each container measures 80 × 120 cm and has five shelves which take 20 flats in total. As it is up to 10 km between the nurseries this saves us a lot of time.

In a discussion of the wastage factor in liner production, the speakers estimated that of the total cuttings taken, 70 to 90% would make saleable liners. This took into account losses during propagation and establishment, outgrading of poor cuttings, etc., and a proportion remaining unsold.

MECHANICAL LIFTING AND COLD STORAGE OF FRUIT TREES AND ROOTSTOCKS

NICHOLAS D. DUNN

Frank P. Matthews, Ltd.
Berrington Court, Tenbury Wells, Worcestershire WR15 8TH

Our nursery produces fruit trees and rootstocks and some ornamental trees. We are wholesale suppliers to the nursery trade and to the fruit grower establishing fruit plantations. We are, therefore, dealing with very intensive field production of bareroot material that necessitates autumn and winter harvest. The majority of our trees are sold as one-year (maiden) trees; this allows us to mechanically lift and store most of these prior to delivery to our customers. Following our tree lifting of around 150,000 trees we harvest ½ million rootstocks from stoolbeds. Due to the deteriorating weather we aim to have all the field work finished by Christmas as we know from experience that we rarely have uninterrupted working conditions in the field after this. This enables us to organise our labour force efficiently, having six weeks work under cover during January and February.

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To enable us to stick to such a tight schedule we, firstly, needed machinery and the capacity to store trees and root-stocks in a suitable environment.

Field Lifting. In the West country we more often than not have a late leaf fall due to a late growing season. Our soil is reasonably heavy therefore retaining warmth for the late growth. We, therefore, aid leaf abscission by the application of copper oxychloride in late September. This gives us a reasonable lifting starting date around 15th October.

We uphold certain theories on the use of machinery in our job. It is possible to become too sophisticated and demanding of the machinery we use. This is particularly the case with machines designed to work in marginal field conditions. Our intention is purely to take the physical work from the operation still allowing due care and attention to the trees themselves. The root system, which tends to be the most neglected part of the plant in our trade, must have the best possible chance of surviving intact when released from the ground. Our machine for this job is a simple side lifter of Danish design that is aided with a shaker to help remove some of the soil. The trees, having been pre-marked into grades, are then bundled, palletised, and put into coldstore. This system enables us to lift a block of trees at a time, cutting out the problem of travelling constantly over the same gorund during the winter, selectively digging to order. This is of great advantage as we do not do unnecessary damage to the soil structure, we have less travelling time for the labour force during the winter season and, most important of all, the physical effort required by each employee is greatly reduced, which improves morale. All palletising and loading during this critical time is done early morning and evenings on a shift system under flood light so that the daylight hours are used in the field.

Cold Storage. The most revolutionary aid to our nursery work over the last 15 years has been the introduction of the jacket coldstore. This was built in 1967 by ourselves with the help and guidance of Mr. Paul Dufresne of Denmark who gave a talk at our 1970 Conference on the jacket coldstore system. I will not, therefore, go into technical details as these are already recorded for your reference but, as the name implies, air is circulated between an outer shell and inner wall, cooling the plants that are in a "still air" environment. This is exclusively used for our own planting material when dormancy is extended into the spring and early summer, if the need arises due to poor planting conditions. The temperature is held at a constant 0° to 1°C, keeping all our planting material in perfect condition. It is well known that coldstored plant material late-

planted is capable of catching up the early planting, even when taken out in the months of May and early June.

To enable us to harvest our trees as mentioned earlier, we needed to apply the same cold storage techniques to trees as we had to rootstocks. A far larger capacity was required but the construction cost for a jacket coldstore of such a size was not economically viable. We, therefore, opted for a direct cold store system that had been used by us quite successfully on a small scale to help with our hardwood cutting technique. Polyurethane foam sprayed onto the inside walls of an existing building created very simply an insulated building into which a refrigeration system was installed to circulate cold air. The only problem that we were aware of was the need to maintain a high humidity in a drying atmosphere.

We manage very well by hand watering the floor of the store twice daily and misting the tree roots twice a week, thereby maintaining the humidity required. As this coolstore is considered short-term and trees are coming in and going out constantly, very few dry out to any degree and after five years experience we seem to have had no problems or reports of desiccated material. In the latter part of the winter, when rootstocks from our stoolbed harvest are kept in these stores, we do then jacket the pallets individually with polythene, which is normal practise in a direct cold store. There are modern systems for creating humidity available now which could be of some use. All these systems produce very fine droplets that are circulated either by the refrigerant system itself or an additional installed fan. We believe that, although a jacket store coldstore is obviously the ideal system for bare root plant material, a direct cooled store with a modern built-in humidifier of accurate control is a very adequate substitute where capital investment is limited. Too high a humidity can create problems of ice deposition on the cooling equipment.

Fungal growth has always been a problem in the still air environment of a jacket store and generally it is best to treat all stock with a fungicide. This is unnecessary in the direct cooled store, therefore being one advantage in the day to day management of the store.

A stacking pallet system was necessary to enable us to efficiently fill the coldstore; these pallets were built by ourselves with manually lift-off tops to enable us to fill each pallet without any damage to the plant material.

Rootstock Harvest. During the three weeks leading up to Christmas we harvest our stoolbeds. An offset saw is used for this purpose as well as ground preparation machinery which has been designed and built by ourselves. Again all stocks are

brought into coldstore where grading and despatch can be done at will, uninterrupted by the weather, allowing prompt delivery to our customers.

In conclusion it is necessary to emphasise the importance of precise organisation where so many extreme situations can affect and disrupt a smooth running operation. At the same time, with so many mechanical and technical improvements as time goes on, we are open to more risks when faults in the system appear. Therefore, careful planning and precise calculations are necessary to make the most of our progress.

STANDARD STEMS FOR ROSES

ANDREW EAMES

Agricultural Development and Advisory Service
Shardlow Hall, Shardlow, Derbyshire

Stems for standard roses are expensive and for this reason some rose growers produce their own. The usual method is to propagate from hardwood cuttings. It is also possible to grow good stems on a stoolbed. A third method, which has been little used by growers, is to bud a "stem builder" on an ordinary bush rootstock and this is what I want to discuss here. At Shardlow Hall we have three years experience budding a range of species and cultivars that seem suitable, using *Rosa corymbifera* 'Laxa' as the rootstock throughout.

Good results have been obtained using *Rosa rugosa*, *R. multiflora* 'Dornloos', *R.m.* 'De La Grifferaie', and *R.* 'G278', an unnamed John Innes seedling, which has produced the best stems so far. *R. canina* selections have been rather disappointing. 'G278' is a very vigorous, upright shrub, and the stems are straight and almost thornless although cuttings do not root readily. The stem continues to thicken as the plant gets older.

Ordinary bush rootstocks are used at normal spacings, although it is important to leave sufficient interrow space to work in when tying up stems in the second year. Good rootstocks and good growing conditions are necessary to give a high proportion of good quality stems and a sheltered site is clearly highly desirable.

Budding is done in the usual way for bush roses. In the second year support is needed and we have used 2 metre canes for staking plus a post-and-wire system. If more than one shoot arises from the bud the best is selected. It is essential to tie in regularly to ensure straight stems (we use a Max

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Tapener). Side shoots must be removed as they arise and, if growth is very vigorous, we tip the shoots when they reach the top of the cane. We have a high proportion of stems fit to bud by August in the first season. Take has been good with 'G278', *R. rugosa*, and *R. multiflora*. We have had a good percentage of saleable standards as a result.

The system fits in quite well with bush rose growing, and does not need extensive stockbeds to provide propagating material and suckering is not a problem with the *R. dumetorum* 'Laxa' rootstocks. So far we have not had much success using *R. dumetorum* 'Laxa' itself as the "stem builder".

IPPS AND ISHS — HOW CAN THEY COOPERATE?

W.-U.v. HENTIG

Institute of Ornamental Plant Research
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The International Plant Propagators' Society (IPPS) and the International Society for Horticultural Science (ISHS) are among the well known and renowned horticultural societies of the world. Main tasks of both these societies are support of horticulture in general and in special fields through improvement of international cooperation in science and in practice.

For some years efforts of both Societies to intensify contacts by means of mutual information and cooperation have increased. For instance, there were discussions on this in November, 1981, between Mr. Raymond Evison, then International President of the IPPS and the author, who was at that time Chairman of the Section "Ornamental Plants" of the ISHS. Leaders of both Societies met at the 21st International Horticultural Congress of the ISHS in Hamburg at the end of August, 1982. Friendly and constructive talks concluded in agreements, which include future regular exchange of information, and the possibility of taking part in meetings, symposia, and congresses of the other society. These agreements have been made with respect and esteem of the statutes and aims of the other society.

To be able to go more into details as to the possibilities of co-operation it is necessary to give more information about the organization and working methods of both Societies.

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For some years efforts of both Societies to intensify contacts by means of mutual information and cooperation have increased. For instance, there were discussions on this in November, 1981, between Mr. Raymond Evison, then International President of the IPPS and the author, who was at that time Chairman of the Section "Ornamental Plants" of the ISHS. Leaders of both Societies met at the 21st International Horticultural Congress of the ISHS in Hamburg at the end of August, 1982. Friendly and constructive talks concluded in agreements, which include future regular exchange of information, and the possibility of taking part in meetings, symposia, and congresses of the other society. These agreements have been made with respect and esteem of the statutes and aims of the other society.

To be able to go more into details as to the possibilities of co-operation it is necessary to give more information about the organization and working methods of both Societies.

The IPPS. It is presumed that the organization and development of the IPPS is well known to plant propagators. In 1951 there were talks in Cleveland, Ohio on the possibilities of the organization of a society which should aim to organize an exchange of theoretical and practical knowledge in the field of plant propagation. Following these talks the Plant Propagators' Society was founded. An antecedent of this society had ceased to exist in 1934. Then in 1961 the International Plant Propagators' Society was founded with the addition of the Western Region in the U.S. Today there are six Regions of this Society, three of these in the United States (West, East, South), one in Great Britain and Ireland, and one each in Australia and in New Zealand. Regions in Israel, Eastern Euorpe, Japan, and Western Europe may possibly be added in the future. Furthermore, there are members in 11 additional countries, which shows the internationality of the Society. At present the IPPS has about 2000 members; all of these are working in the field of plant propagation as nurseryman, scientist, teacher, or advisor. The fields of ornamental plants, tree nurseries, and fruit trees are particularly well represented. The IPPS publishes a "Combined Proceedings of the Annual Meetings," and a quarterly bulletin, "The Plant Propagator". The fundamental principles of the Society are ready exchange of knowledge among the members and suggestions on further successful experiments. This is the idea behind the slogan, "To Seek and To Share".

The ISHS. Even before the establishment of the ISHS, International Horticultural Congresses had been held, beginning in 1889. Organization of such congresses was always done by a "Committee for the Preparation of International Horticultural Congresses". But it was only at the 14th International Horticultural Congress (1955) in Scheveningen, Netherlands, that a proposal was made to put "Society" in the place of "Committee". Then, at the 15th International Horticultural Congress (1959) in Nice, France, it was agreed to do this and, in the same year, the ISHS was founded in Paris.

The general objective of the ISHS is the advancement of horticulture by the improvement of international cooperation in science and technology. The means available to ISHS for the achievement of this objective are:

1. The arranging of an International Horticultural Congress every four years.

2. The setting up of Sections dealing with groups of horticultural plants, of Commissions engaged in various scientific and technical aspects of horticulture or special groups and, for both, the setting up of Working Groups.

3. The organization of Symposia on specific topics for scientists and other specialists.

The management and organization of ISHS is in the hands of the Council representing more than 45 individual countries. The scientific and technical work is carried out by the sections, commissions, and their working groups under the supervision of the Executive Committee, which assists the Council.

The sections and commissions are at present as follows: Sections for fruits, vegetables, ornamental plants, medicinal, spice and aromatic plants. Commissions for nomenclature and registration, economics, engineering, protected cultivation, plant protection, plant substrates, labour and labour management, tropical and subtropical horticulture, and urban horticulture.

The ISHS publishes:

1. "Chronica Horticulturae", the bulletin of the Society, three times a year.

2. "Scientia Horticulturae", responsible for scientific contents, published monthly.

3. "Acta Horticulturae", a series of scientific and technical communications, mainly proceedings of the ISHS symposia.

4. The "Proceedings of the International Horticultural Congresses."

5. "Horticultural Research International", containing information on horticultural research in some 61 countries, listing about 1400 horticultural research institutes and about 14,000 research workers, with main fields of interest (3rd edition, 1981).

At present there are more than 2,000 individual members from more than 90 countries all over the world. These members are persons who are engaged or interested in scientific, technologic, or economic problems or who work in the field of education of horticulture or in amateur horticulture. Besides, more than 200 institutes or organizations are affiliated members of the ISHS.

Recently, from August 29 to September 4, 1982 in Hamburg Germany, the work of the ISHS became apparent at the 21st World Congress, in which 2200 persons from 77 countries — some of them members of the IPPS — took part.

Possibilities of closer cooperation. To intensify the cooperation between IPPS and ISHS it seems to be necessary to name *responsible persons* for development and maintenance of contacts between both Societies. Uninterrupted correspondence and talks with each other and the development of personal

contacts are the presupposition for lasting cooperation. As we know, this problem has been solved for the ISHS and the three regions of the IPPS in the United States. Prof. H.B. Tukey, Jr., Director of the Center for Urban Horticulture at the University of Washington, Seattle, Washington, at the present time being President of the ISHS and a member and Past President of the IPPS, has worked successfully towards this for some time. In Europe, the author has been appointed by the Council of the ISHS as a liaison officer for contacts with the IPPS in the Region of Great Britain and Ireland. Until now the ISHS has not appointed a liaison officer for the IPPS Regions in Australia and New Zealand, but it is known that the ISHS Symposium on Plant Propagation, planned for May, 1984, is prepared in close cooperation with the IPPS Australian Region.

A most important point is *mutual information*; this also applies to fixing of dates. It should enable the members of both Societies to attend meetings, symposia, congresses, etc. which are of interest to them. Besides, it is of utmost importance to inform the other partner about events that could be of interest to its members, also about interesting publications or other items. This information could be given through "The Plant Propagator", "Chronica Horticulturae", or through special circulars to the members. For instance, members of the ISHS Section, "Ornamental Plants", have been informed about the present IPPS meeting in Aberdeen, Scotland, by circulars. To reach the members of the ISHS, the IPPS could also take advantage of other channels such as informing the correspondents of the ISHS in, at present, 26 countries through whom the corresponding national technical press could be reached. For the past 1½ years the German technical periodicals get information on the IPPS through this channel. It has to be checked how the ISHS could achieve this distribution of information. The most important task of the liaison officers, in any case, is mutual information. Furthermore, both Secretariats have to coordinate the dates of events.

It is indispensable that the officials of both Societies know each other. This can be achieved by mutual invitations and organized meetings at the respective events. For instance, officials of the IPPS participated in the 1982 meeting in Hamburg at the invitation of the section "Ornamental Plants" of the ISHS. The ISHS has the intention to inform the members of the IPPS especially on events and activities with the main topic of plant propagation. Two such symposia are already planned, as mentioned before, one for 1984 in Ringwood East, Victoria, Australia, and another for 1987 in Geisenheim/ Rhine, Germany F.R. But the topic of plant propagation will

also be of importance at other symposia and at the 22nd World Congress of the ISHS in Davis, California, in 1986.

The symposia and congresses give another opportunity for close cooperation. For example, one could think of asking members of the other society to lecture about topics of special interest. Such invited speakers are well known specialists who can give learned information. But members of both Societies should have the opportunity to present contributed papers. The kind invitation to deliver this speech is a good example for this practice and I thank the responsible persons of the IPPS very much for it.

Another possibility for intensifying the contacts could be mutual help in organizing group excursions or single visits to institutes or firms specialized in plant propagation. Last but not least, one could also plan excursions and meetings of both societies together.

SUMMARY AND OUTLOOK

This contribution started with a description of the latest efforts for closer contacts between IPPS and ISHS. It has tried to outline the organization and working methods of both Societies, and to give proposals on closer cooperation such as:

Nomination of more liaison officers.

Common planning of the calendar events and mutual information.

Closer cooperation of secretariats and officials.

Invitations to conferences, symposia and congresses.

Group and single visits to institutes, nurseries, or other places specialized in plant propagation.

Common excursions and meetings.

Realization of such proposals cannot be done in weeks or months, but only in years. But if we continue to work in the way we have started, in mutual confidence and respect, then we will achieve the aim of closer and continuous cooperation to the benefit of the members of both Societies and to the advantage of horticulture as a whole.

PROPAGATION SYSTEMS IN NEW ZEALAND AND A MEANS OF COMPARING THEIR EFFECTIVENESS

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Aided by an amenable climate and driven by the need to diversify its economy, New Zealand has increased its horticultural production almost five-fold in the last decade. The average daily radiation in N.Z. exceeds that in Britain in all seasons but the most notable difference from a horticultural viewpoint occurs in winter, when N.Z. receives up to eight times as much radiation (Table 1).

Table 1. A comparison of radiation levels in New Zealand and Britain. (MJ/ m^2 day total short-wave radiation: June, December, and average).

	Low	High	Average
New Zealand, 34 to 47° South latitude:			
Auckland	6.8	22.7	14.8
Wellington	5.2	22.9	14.0
Christchurch	5.0	24.2	14.2
Invercargill	3.6	22.3	12.6
Britain, 50 to 59° North latitude:			
Aberdeen	0.8	16.9	7.8
Southport	1.5	17.8	8.8
W. Sussex	2.3	18.8	10.2

Data from: Benseman & Cook, 1969. N.Z. *Journal of Science* 12:696-708, and Taylor and Smith, 1961. *Meteorological Magazine* 90:289-294.

Because of this mild winter climate, New Zealand is able to enjoy a very varied garden flora including a wide range of introduced temperate and warm-climate species. Both botanic and domestic gardens display many plants wholly familiar in Britain (*Spiraea, Forsythia, Philadelphus, Magnolia, Rhododendron*, etc.) as well as those N.Z. natives "naturalized" in British horticulture long ago (*Hebe, Olearia, Griselinia, Pittosporum, Senecio greyii*), and some less commonly seen in the United Kingdom (*Dodonaea, Clianthus, Aristotelia, Coprosma, Sophora, Phormium, Dacrydium*, the beautiful tree ferns, *Cyathea* and *Dicksonia*, and many others). In addition, *Nerium* from the Mediterranean region and many Proteaceous shrubs from Australia and South Africa, enrich the New Zealand scene.

Diverse propagation systems are employed to produce these many plants. They range from simple outdoor mist or low, polythene-covered frames (both without bottom heat), to standard glasshouse methods using polythene, mist, or fogging. Most frequently, propagation houses are plastic-covered tunnels, usually with forced ventilation but, in recent years, steel-framed industrial buildings clad with rigid PVC sheeting have proved increasingly popular. Misting equipment is extremely

varied, with nozzles and controllers of both local and imported origin. Controllers based on sequence timers, evaporation balances, solarimeters, or "artificial leaf" sensors (operating via changes in capacitance, A.C. or D.C. resistance), are all used. These give mist bursts that may vary in duration from as much as 1 to 30 seconds.

Faced with this diversity of systems and structures, it would be useful if a standard method were available for comparing their relative effectiveness. Since the aim of all propagation systems is to preserve the water status of unrooted cutting material, then a determination of the evaporation rate from a leaf-like surface placed amongst the cuttings is the appropriate required measurement. Such an evaporimeter would need to be unusually sensitive because evaporation rates in propagation systems are, by design, very low. At the Levin Horticultural Research Centre in New Zealand, Stephen Butcher and I developed a simple, inexpensive instrument which proved effective for this purpose.

The Levin Evaporimeter. The design differs from most evaporimeters in that it incorporates a surface to intercept mist and radiation as does foliage. Thus it benefits from evaporative cooling as do misted leaves (i.e. the evaporation rate is slowed), while increased radiation speeds evaporation. It consists of a horizontally-positioned, 2 ml graduated pipette with a square of filter paper (area 1000 m^2) mounted at one end (Figure 1). The filter paper has a "tail" which is wrapped around a short piece of PVC-covered wire and is pushed into the open end of the pipette to achieve a snug fit. The filter paper is backed with black, sticky polythene or PVC tape, which at its margins is folded over a supporting former of thin wire, to complete the "target" surface.

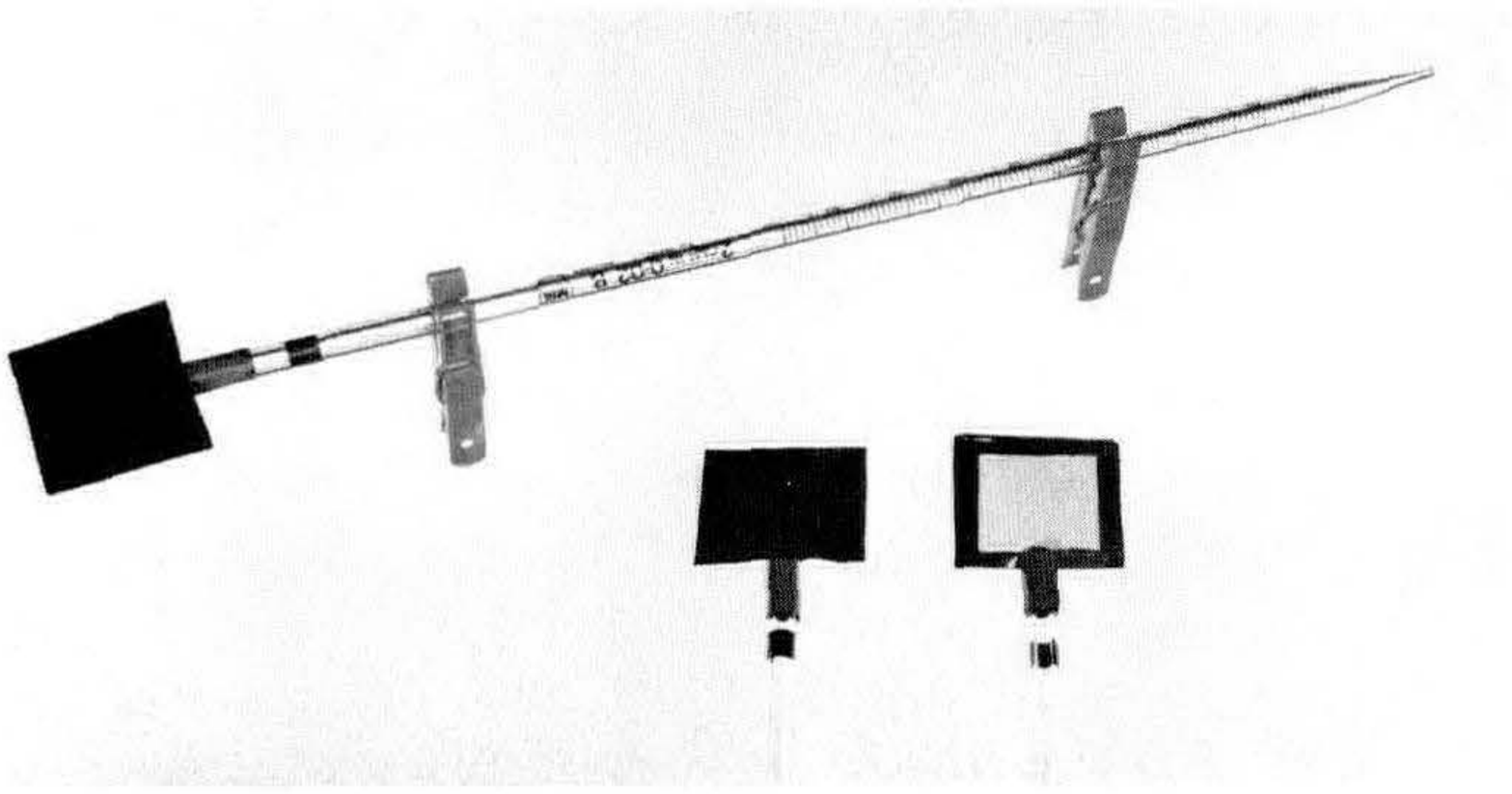

Figure 1. *Top.* The Levin Evaporimeter. *Below left:* the upper, tape-covered surface is supported by a thin wire former. *Below right:* the lower, filter paper evaporating surface has a "tail" which wraps around a short piece of PVC-covered wire and is pushed into the pipette.

After filling with water from a tap or squeeze bottle, the evaporimeter is mounted horizontally (using a spirit level), tape face uppermost, amongst the cuttings in a propagation tray. Plastic clothes pegs provide useful supports for the pipette. Evaporation from the filter paper causes the water meniscus to move along the pipette and, from readings at hourly intervals, the evaporation rate can be calculated as micrometers of water per hour (μm/h). If the tape surface is misted, then evaporating cooling serves to slow water loss from the filter paper beneath it. An increase in radiation warms the surface and increases evaporation.

Results of a comparison of three systems are shown in Figure 2. These were conventional open mist, mist enclosed within a polythene tent, and a polythene tent without mist but incorporating an irrigated peat/pumice base. In all cases evaporation increased with radiation but the superiority of the closed mist system is evident at all light levels. The frequency of misting was timer-controlled to give a 7 second burst every 20 minutes, but this was apparently insufficient at high light, as indicated by the non-linearity of the fitted curve.

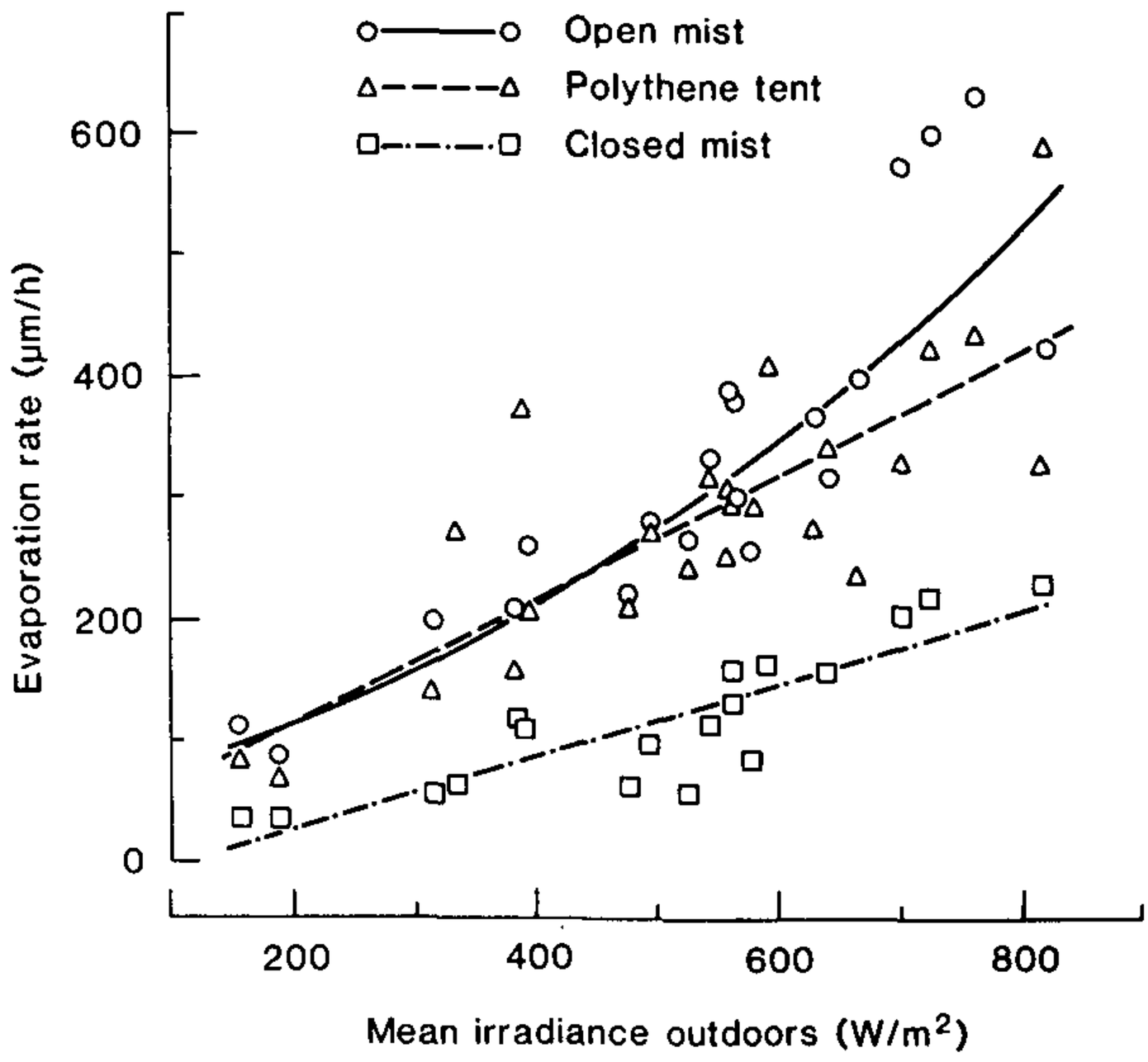

Figure 2. Evaporation rates measured in three propagation systems at a range of light levels. Open mist = ○; closed mist = □; polythene tent = △.

Rooting trials in open and closed mist have shown that improved rooting does not necessarily follow from reduced evaporative conditions in the latter system. The higher tem-

peratures that result from enclosing the mist can detrimentally affect rooting, particularly in the case of conifers. However, when cuttings of *Hebe elliptica* were propagated under mist in a controlled-environment room held at 20°C, rooting correlated closely (r = −.940) with the evaporation rates recorded under six different light treatments (Figure 3). The corresponding correlation between rooting and light level was less close (r = −.728) which suggests that evaporation rate was the more significant influence.

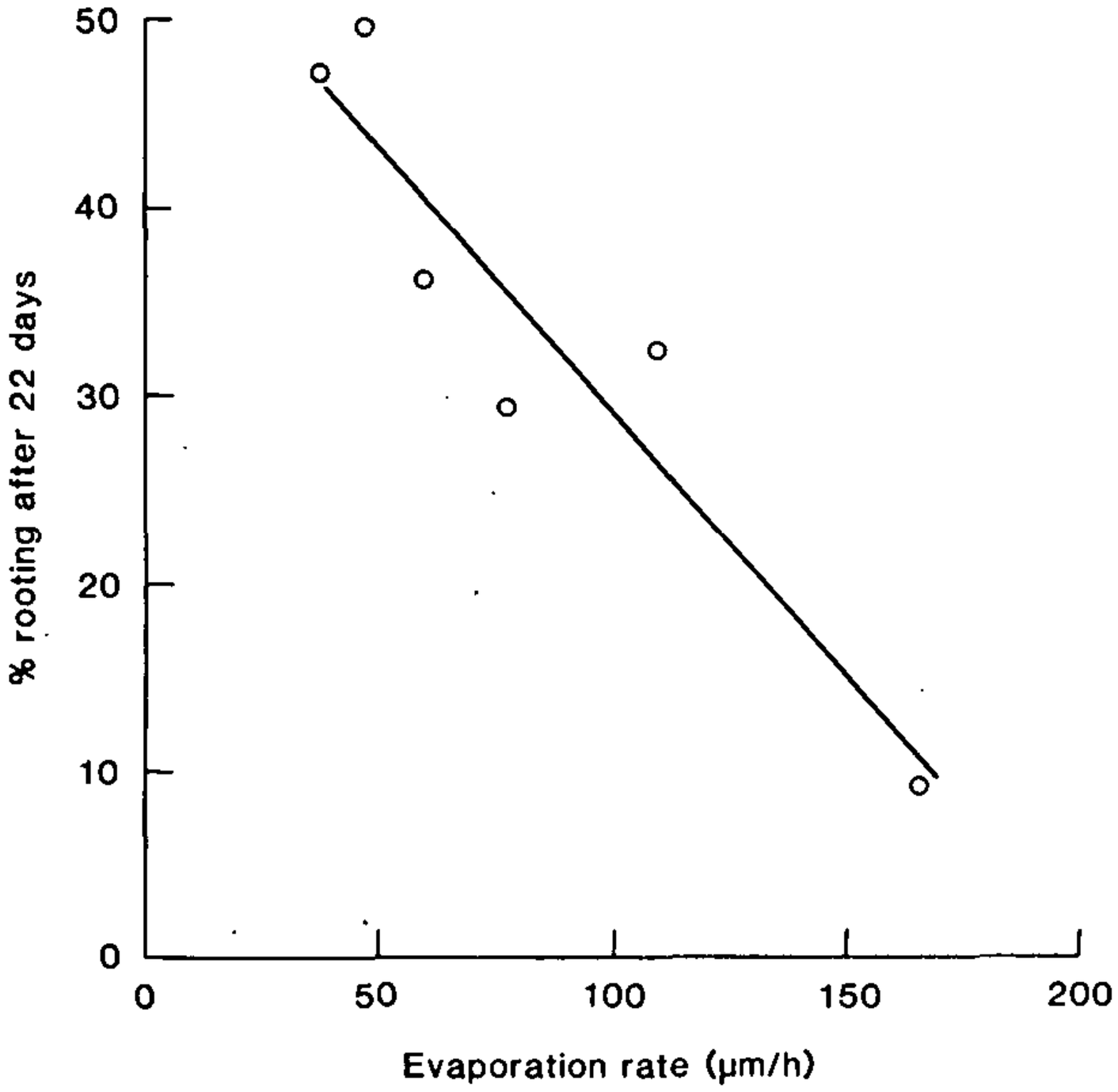

Figure 3. Rooting of *Hebe elliptica* cuttings in relation to the evaporation rates measured under six different light treatments in a controlled environment at 20°C. Rooting was scored 22 days after insertion.

Besides comparing various propagation systems, the evaporimeters have been used to test mist control systems (timers vs. different types of electronic leaf), and to check for uniformity of evaporation conditions across a propagation bench. They are useful to determine whether any propagation system is performing adequately.

Acknowledgements. This work was supported by the New Zealand National Research Advisory Council during my tenure of a Senior Research Fellowship at the Levin Horticultural Research Centre.

EVALUATION OF CHARLTON THERMOSYSTEM BASE HEATING APPARATUS

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The distinguishing features of the Charlton thermosystem are the use of a special-purpose transformer to supply a low voltage to the load, and of a heavy 4 cm diameter steel hawser connected to the transformer secondary winding as the heating element for use in propagation beds. The hawser has a very low electrical resistance and, therefore, draws a large current from the transformer even at a very low secondary voltage. Delivery of a desired level of power as heat to the bed depends on correct matching of the hawser length, (i.e. its resistance), to the characteristics of the transformer.

The design data, on which this matching is based, is confidential to the manufacturers. The important practical feature of the system's operations is that the desired heat output can be delivered to the hawser while keeping it at so low a voltage that no electrical insulation of the hawser is necessary. Even when laid in a damp medium such as moist sand any leakage currents which occur in the medium are entirely negligible relative to the large current in the hawser and, therefore, no short-circuiting effect arises. This, of course, also means that the heating element in the bed is completely safe. The Charlton transformer can be adjusted by means of an output switch to any one of three output settings — high, medium, or low. This allows a more even flow of heat under conditions where demand for heat is considerably lower than the full rated output of the transformer.

EXPERIMENTAL PROCEDURE

Apparatus. An experiment was carried out in which the performance of the Charlton system was compared with that of a conventional mains-voltage soil-warming cable as heating elements for maintaining base temperatures of a desired level for rooting a range of ericaceous cuttings. The two systems were installed in identical insulated propagation beds, one on each side of the central path in a 5.2 m wide polythene tunnel greenhouse. The beds, insulated at base and sides with 2.5 cm thick polystyrene, had dimensions of 18 m × 2.0 m. The cable of the conventional system and the steel hawser of the Charlton system were each laid on the insulated base and covered with sand to a depth of 10 cm. A noteworthy difference be-

tween the two systems lies in the spacing between the current-carrying elements in the two cases. The conventional cables are spaced 7.5 cm apart, but this spacing is not practical for the much heavier steel hawser. Three loops of the hawser, running the full length of the bed, were connected to the transformer. Hence, there were six lines of hawser in the 2.0 m wide bed and the effective spacing was 30 cm. Attention was given to any possible effects of this difference in spacing on uniformity of plant development.

Similar thermostatic controllers were used to control the supply of power to both systems. The controllers had multiple sensing elements distributed over the bed area so that temperature was controlled at a level representative of the average conditions in the bed. Temperatures at several points in the bed, in the air, in the greenhouse, and in the air outside were recorded during the experiment, using thermocouples and a multi-point chart recorder.

The two systems began operation on November 11, 1981 and monitoring of their performance continued until March 5, 1982. During this period a wide range of outside temperature conditions was experienced, ranging from very mild to one period when minimum night temperatures as low as −10°C were recorded.

The power consumption of each system was measured with a commercial kWh meter, which was read daily.

Plant Materials. In the clear, unheated polythene tunnel a total of 10,000 cuttings of *Rhododendron*, *Azalea*, *Pieris*, and *Andromeda* was inserted in each bed. Of this number 8,000 were propagated in open mesh polypropylene boxes containing a rooting compost of two parts peat to one of sand, whilst the remainder were inserted directly into this compost overlying the cables, without being boxed. All cuttings were treated with 0.8% IBA powder and each bed was covered by light gauge polythene.

A setting of 17°C was made in the separate cable systems by means of the electronically operated thermostats. Base heating commenced in early November, two days before the cuttings were inserted. Rooting commenced at different times for each of the plant groups, but rooting in all plants was recorded 2½ months after insertion.

RESULTS

The main conclusion reached from physical aspect of the experiment was that there was no measurable difference between the performance of the two systems. The power rating of both systems, within the limits of accuracy of the kWh

meters used, was 2.5 kW (Charlton system on its maximum setting).

In the coldest weather experienced during the test, neither system was capable of maintaining the bed temperature at the set level of 17°C, at certain times the temperature in both beds dropping to as low as 12°C. No difference between the temperatures actually maintained in the two beds was discernible. The principal point of interest was whether any appreciable difference in power consumption would be measured over an extended period of operation of the two systems under similar conditions. It is seen from Table 1 that the difference in consumption between the two systems over a period of 54 days was only 64 kWh or 3%. This difference is within the limits of accuracy of the control and measuring instruments used.

Table 1. Power consumption of Charlton and conventional soil warming systems. November 26, 1981 - January 19, 1982.

System	Power Consumption (kWh)
Charlton	2287
Conventional	2351

During the subsequent period, from January 19 to March 5, a somewhat larger difference — 1114 kWh as against 1241 kWh for the Charlton and conventional systems, respectively, was recorded. This difference, however, is accounted for by the fact that during much of this period the Charlton system was operated at a lower output setting and, in consequence, at times of high demand the temperature it maintained in the bed was lower than the temperature in the comparison bed. There was no evidence that any true economy could be achieved through use of the lower settings.

In view of the different conductor spacings associated with the two systems the effects of this on bed temperature were examined. It was found that greater non-uniformity of temperature within the sand of the bed occurred as a consequence of the wider spacing of the Charlton system. However, the depth of the bed was sufficient to prevent this non-uniformity being reproduced in the boxes placed on top of the sand, in which cuttings were actually rooted. This, in turn, was reflected in the absence of any non-uniformity in the rooting of the cuttings themselves. Therefore, it was concluded that the wider spacing associated with the Charlton system did not represent a disadvantage of any practical consequence for the application being studied. There was no significant difference in rooting performance of cuttings between the base heating systems. Percentage rooting is shown in Table 2.

Table 2. Comparison of mean rooting percentages of a range of Ericaceous cuttings in two base heating systems.

Species and Cultivar	Conventional	Charlton
Rhododendron 'Cunningham's White'	76%	76%
Rhododendron 'Cynthia'	44	56
Rhododendron 'Fastuosum Flore Pleno'	100	100
Rhododendron 'Lord Roberts'	66	70
Rhododendron 'Nova Zembla'	42	48
Rhododendron 'Baden-Baden'	70	52
Rhododendron 'Cowslip'	92	98
Rhododendron 'Scarlet-Wonder'	63	66
Azalea 'Florida'	80	78
Azalea 'Vuyk's Rosyred'	99	99
Andromeda polifolia	96	93
Pieris 'Forest Flame'	93	95

There was no significant difference in the speed or extent of rooting where cuttings were inserted directly into the compost overlaying the cables. It was however noted that rooting in the areas directly over the cables of the Charlton system was slightly higher than in areas between the cables.

CONCLUSIONS

Under the conditions of this trial the Charlton Thermosystem was satisfactory for the propagation of the species selected. The results were as expected considering the regime of heat supplied. The Charlton system is simply and speedily installed, as well as being easily transferred to other locations. It also has a high safety rating because of its low operating voltage.

During discussion following this paper, other members agreed with the Kinsealy results and the relative costs of electricity consumption for the two systems. Efford E.H.S. found there was no saving in electricity with using the hawser and it needed a thermostat to prevent overheating. It was emphasized that any hawser could be used. The major installation cost is that of the transformer, from £500 to £1100, depending on size.

DEVELOPMENTS IN NURSERY STOCK PRODUCTION IN ISRAEL

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Horticultural practice in Israel goes back to Biblical times. Five of the seven species mentioned in Deuteronomy 8:8 are fruit trees. "The Lord your God is bringing you to a land of wheat and barley, of vines, fig trees and pomegranates, a land of olives, oil and honey." In Leviticus 19:23 the laws concerning the culture of fruit trees are laid down, "When you enter the land and plant any kind of tree for food, you shall treat it as bearing forbidden fruit. For three years it shall be forbidden and may not be eaten, in the fourth year it shall be a holy gift unto the Lord, and this releases it for use. In the fifth year you may eat its fruit and thus the yield it gives you shall be increased."

The Mishna, which was written in the 2nd century, sets out very definite do's and don'ts as far as grafting is concerned, indicating that our forefathers were very imaginative propagators. I quote from Order Zeraim — (Seeds), Tractate Kilaim Chapter 1, verses 7 and 8.

7. One kind of tree may not be grafted on to another kind, nor one kind of vegetable on to another kind, nor a tree on to a vegetable, nor a vegetable on to a tree. Rabbi Judah permits (the grafting of) a vegetable on to a tree.

8. Vegetables may not be planted in the stump of a sycamore tree, nor may rue be grafted on to white cassia, since that is to graft a vegetable on to a tree. A fig-tree shoot may not be planted in scutchgrass that this may shade it, nor may a vineshoot be trained into a watermelon that this may pour its juice into it, since that is (to graft) a tree on to a vegetable.

In a short presentation we must skip 1800 years and start with the modern nursery industry in Israel which is, in fact, a reflection of the development of agricultural settlement of the land.

It all began about 100 years ago when the first settlers of agricultural land who, amongst other things, planted vineyards and almond groves. This was followed by planting of orange groves and other fruit orchards. Much of this early horticulture was financed by Baron Edmond de Rothschild and was supervised by French farm managers and advisors.

Following World War I and the Russian revolution large numbers of immigrants started arriving in the country, at first

from Eastern Europe and later, in the late twenties and thirties, from Germany. It is in these years that the nursery industry really got going. In addition to fruit tree nurseries, especially citrus, there is record in the early thirties of four large nurseries which produced garden plants and even house plants.

It is impossible to cover even the period of the past 60 years in a short time; I have, therefore, chosen to describe some of the developments from a very specific point of view and I hope that this will illustrate the tremendous changes which have occurred in what is in effect a relatively short period in horticultural experience.

I will begin with citrus — historically and also today our number one export crop. Although oranges were introduced into the country in the 14th century, citrus growing became widespread only in the 18th century. We have records of citrus fruit exports from 1855 onwards; in that year, more than 100,000 boxes of fruit were shipped to Europe. The crop had its ups and downs and both Arabs and Jews planted and cultivated citrus groves. Traditionally, sour orange or sweet lime were sown in the field as rootstocks and these were grafted *in situ*, often on framework branches of 1 to 1½ year-old seedlings.

In the 1920's, methods prevalent in the U.S. were adopted and grafted nursery stock became available. Both *in situ* grafting and grafted stock were used in the great expansion of the citrus acreage in the coastal plain between the years 1925 to 1936. Thirty thousand hectares (75,000 acres) were planted. In 1938, a record 1.5 million boxes of fruit were exported.

World War II, followed by Israel's War of Independence, left their mark of damage in the citrus groves. In 1949 only 10,000 hectares remained alive.

The waves of mass immigration into Israel in the early 1950's brought, in its wake, massive planting of citrus groves. This included replanting of war-neglected orchards as well as the opening up of new areas to citrus growing: the northern Negev, the Bet Shean valley for early grapefruit, and Upper Galilee. All this acreage was planted with nursery-grown stock but the old controversy as to whether nursery grafted or *in situ* grafted trees were preferable arose again.

Inexperienced growers planted either balled or bare-rooted rootstocks which were later grafted by travelling teams of propagators. It is only since the mid-1960's that all planting is done with nursery-produced grafted trees.

Since the late 1920's propagators selected their scionwood from healthy, heavily-bearing trees. Inspection of nurseries for plant health was introduced in 1939 under the laws of the British Mandate and a certification scheme for registered psorosis-free source trees was introduced in 1953.

At the end of the 1960's, tristeza, the dreaded virus disease which has caused so much damage in many citrus growing areas of the world, was diagnosed in Israel. This changed the whole approach to citrus nursery production. As part of the tristeza suppression programme, it was decided that in order to supply growers with virus-free, especially tristeza-free trees, the nurseries would have to go into insect-free conditions.

It was impossible to move the nurseries into areas isolated from the citrus groves and, therefore, all citrus nurseries are now housed in insect-proof screen houses. The source of propagating material is registered mother trees which are regularly inspected and tested for virus twice a year. Some of these are still in open orchards. There are a small number of registered mother tree collections in insect-proof screen houses and the Ministry of Agriculture is now establishing a citrus repository in an isolated area.

Virus-free material has been produced by shoot-tip grafting at the Agricultural Research Organisation. The first trees so produced are now being tested.

Cultural practices changed rapidly in the citrus nursery during the 1970's. Container growing became common and containers were lifted off the soil onto benches. Sprinklers were replaced by individual pot drip irrigation.

With the necessity of housing all citrus nurseries under expensive insect proof conditions, intensification was required. Shortening the period in the nursery became necessary and increasing the number of plants per unit bench area was essential. This became possible with the introduction of lighter potting mixes combined with regular and frequent irrigation and feeding, much of which is controlled by computers.

Citrus planting has virtually stopped in Israel and our nurserymen are looking for alternatives. Some of them have gone into the production of ornamental, miniature citrus trees. These include calamondin, kumquats, and limequats.

Cuttings are rooted all year under mist with bottom heat giving 28°C in the rooting medium.

Some of the products are grafted to produce a miniature tree as opposed to the traditional bushy American calamondin.

I have mentioned certification schemes earlier and would like to broaden the discussion on this subject because it has bearing on so many of our nursery crops.

Israel is a very small country, with areas of different climatic conditions within short distances. A variety of crops, for example, deciduous fruits and citrus, are grown in close proximity. This gives many pests, and even some diseases, easily available alternate hosts throughout the year.

Being a small country has the advantage that efficient inspection services are relatively easy to implement. Most of our compulsory certification schemes were initiated by growers who put pressure on the Plant Protection Services to make the regulations.

In contrast to many other countries, certification of nursery stock and nursery inspection are compulsory for many crops. These include citrus, grapevines, avocadoes, deciduous fruit trees, roses, carnations, and gladioli. There are others like mango, olives, and peaches which have voluntary source-tree registration schemes.

I shall briefly describe the grapevine and carnation programmes because these illustrate well how nursery practice changes with a change in emphasis on plant health.

The vine certification scheme is based on one national repository which was planted in an area isolated from commercial vineyards.

Since local vineyards were 100% infected with fan-leaf virus, the source material for the repository was imported as virus-tested material from California and Super Elite material from France. Some of our local cultivars have been added to the collection following thermotherapy.

The canes which come from the repository are cut and graded by machine in the nursery. They are table-grafted in February or early March. No tying is done, the grafts are dipped in a heated plastic compound called 'koffer' and are left to callus in sawdust-filled boxes. There are two methods of planting. Traditionally callused grafts are planted in the field in spring, are lifted at the end of the growing season, and are planted in the vineyard in winter. However, due to the problem of virus-transmitting nematodes, container-grown plants raised off the soil are becoming more common. These are potted in the spring and are planted in the vineyard in summer after only 2½ to 3 months' growth in the nursery.

The older nurserymen still prefer the field-grown plant; however, the demand for container-grown plants is on the increase. Phytosanitary superiority is not the only reason. If

you remember the verse I quoted at the beginning of this paper and the fact that early fruit is forbidden from a religious point of view for consumption or for wine making, summer planting before the beginning of the Jewish New Year in autumn has the advantage of counting for an extra year. The grower may therefore market his grapes one year earlier.

Since the introduction of certified planting material, grape yields have increased markedly — from 30% in some cultivars to fourfold in others.

The compulsory carnation certification scheme grew with the development of the carnation flower industry. Prior to 1972 carnation propagating material was imported from Europe annually. At that time no high quality virus-tested material was available for spray carnations and many diseases were imported with the mother plants. The nurseries grew mother plants in the field, practicing crop rotation with other crops they cultivated.

A "clean stock" research and development program was initiated at the Agricultural Research Organization by the Ministry of Agriculture and the Flower Growers' Association. Close cooperation between the Departments of Floriculture and Virology brought early results. Meristem culture-derived plants formed the basis of the clean stock programme. Rigorous horticultural testing and a strict "generations" schedule was developed. The scheme is based on three propagation stages. The pattern adopted, as well as the nomenclature, were adapted from that used by the British Nuclear Stock Association.

We have nuclear stock stage foundation nurseries and certified nurseries. All stages in this certification scheme are inspected by the Seed and Nursery Inspection Services of the Ministry of Agriculture.

The nuclear stock and foundation nurseries are in insect-proof screen or glasshouses. Nuclear stock is grown as individual plants in pots. They are tested for virus three times a year and all cuttings supplied to the foundation nursery are indexed for *Fusarium*.

Nuclear stock and foundation stock cuttings are all rooted in Speedling trays. Some of the certified nurseries supplying the flower grower also use Speedling trays for rooting.

Foundation nurseries, as said before, are in insect-proof structures, the benches are raised, and clones within a cultivar are kept separate. The certified nurseries are all under cover now and the plants are grown in detached beds or raised benches. Only drip irrigation is permitted and all growth media are sterilized.

The great boom in expansion of carnation acreage in which areas under this crop doubled for three years running, has come to an end. A recent development in our carnation propagation nurseries is the search for an alternate crop to fill the rooting benches in quiet periods and even out the work schedule of the staff. Pelargonium cutting production fits in well with carnations.

Carnation mother plants are planted in October. Cuttings are marketed in June and July for local planting.

Nurseries which export carnation cuttings do so mainly between December and April, their peak marketing period being from February onwards. Pelargonium mother plants are planted at the end of June and cuttings are marketed from November to February. In this way "all-year-round" production is achieved.

I have put great emphasis on changes in nursery practice following the efforts made to produce healthier plants. There are, of course, many developments not directly connected with certification schemes and I shall have to leave many sides of nursery production uncovered. To finish off, I should like to mention very briefly a small number of newer nursery practices which are in use in Israel.

Softwood cuttings of stock which has traditionally been known as difficult-to-root are rooted under mist. One example is the local apple rootstock, 'Hashabi'. Clonally selected mother plants grown in the greenhouse are pinched frequently. Cuttings are taken every three weeks. To save labour, a bunch of cuttings is harvested without paying attention to the position of the cut or the size of the cutting, as long as it has at least three pairs of leaves. The cuttings are inserted into a very light medium as a bunch, saving the time of individual striking. Rooting percentage is somewhat lower than individually struck cuttings but the time saved well compensates for this. Some of the Malling-Merton apple rootstocks are treated similarly but here etiolation is required. A method adapted from avocadoes is being used.

Olives, which traditionally were planted as grafted trees, are all being propagated by rooting cuttings under mist.

Peach hardwood cuttings are rooted during winter *in situ* for high density meadow orchards.

Tissue culture is used for propagation of many plants, especially house plants. Material which is in short supply in the country, like apple 'MM 104' rootstock, or new cultivars of bulb and corm crops bred in Israel, are being bulked up. Similarly, new introductions, especially plants with floricul-

tural potential from the southern hemisphere are being propagated in tissue culture laboratories.

Hydroponics for propagation: The Ein Gedi system is used for growing-on of tissue-culture derived plants. Market size plants of philodendron, for example, were obtained in a shorter time than under conventional growing-on conditions. Furthermore, the system is used for growing of mother plants. The number of dieffenbachia or dracaena cuttings produced per unit time and area is considerably larger than under normal greenhouse conditions. Rooting of cuttings has also been found to be faster.

I have said nothing so far about nurseries producing garden plants or forestry nurseries. We, of course, have these too and progress is being made in their production methods. However, developments here are generally slower and perhaps less dramatic. This is probably due to the fact that to date, their products have not been geared to export and they are not part of horticultural food production.

Israel's nursery industry is dynamic. It is continually changing with progress in horticultural practice and with the need to adapt to changing attitudes to our environment, and changing trends in our export market.

ORNAMENTAL NURSERY STOCK PRODUCTION — WHAT IS ITS FUTURE?

D.N. CLARK

Notcutts Nurseries Ltd.
Woodbridge, Suffolk

MARKET POTENTIAL

We must first consider what is the market potential of our industry. I firmly believe that this can be described as good, as so many factors point to an increased size of market. A number of factors will increase the size of the market:

a) Increased leisure time.

b) Increased awareness of the environment and the role of plants in that environment.

c) The introduction of fashion to gardening, which will make the public want to change their gardens to keep up with the Jones's.

d) Introduce new dimensions to the garden, such as night lighting and tub gardening. The recent introduction of peat

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d) Introduce new dimensions to the garden, such as night lighting and tub gardening. The recent introduction of peat

growing modules for the growing of tomatoes and other vegetable plants is a very good example, where a total market has been expanded.

e) Our continued desire to have something new and, therefore, the continued potential for new plants.

CAN WE REALISE THIS MARKET POTENTIAL?

If the existing industry (and I particularly refer to the existing Nursery and Garden Centre industry), does not realise the potential of this market, other sectors of the retail market will certainly capitalise and develop the potential if we do not; I, of course, refer to the giants of the retail trade, who are only now just starting to be active in the British Isles. The market potential will be realised in a number of ways, including:

a) Expansion of sales outlets and also the expansion of places where hardy plants are sold.

b) Better presentation of products

c) Improvements in servicing of retail outlets

d) Promotion of new plants

e) Introduce fashion to gardening

f) Introduce new dimensions to gardening

CAN THE INDUSTRY PRODUCE THE GOODS?

I am quite confident that our industry will have the technology and ability to produce the goods but my biggest fear is that we will be tempted to over-produce, with the inevitable adverse effect on pricing. It is most important that we, as an industry, try and plan together and avoid falling into the trap. I am sure our fellow IPPS members from the U.S. will be able to illustrate the disastrous effect of over-production that junipers has had in the States and the effect on pricing in recent years.

However, we have yet to experience the full effect of massive dumping by third parties. This is now beginning to significantly effect prices in Scandinavia and Western Germany and it will be inevitable that we will also be affected by cheap production coming into this country from Eastern Block countries and possibly from the new European Economic Community members.

It is appropriate to mention at this point that during the past decade, British nurserymen have made more progress in improving quality and adapting to the needs of the market, than any other country in Europe. Our Research & Development services have made important contributions to this progress and the industry has taken full advantage of their efforts.

WHAT ARE THE MAJOR CHANGES THAT WILL OCCUR IN OUR INDUSTRY TO ENABLE US TO MEET THE DEMAND OF THE FUTURE?

a) The larger nurseries will get larger to maximise the potential of saving by scale of production.

b) The small specialist nurseries will continue to survive by growing either a few lines exceptionally well, or a reasonably wide range of rare plants or specialising in young plants.

c) While labour costs will continue to rise ahead of selling prices, the industry will continue to take advantage of new technology as well as utilising new equipment and modern management techniques.

The role of new technology. New technology will enable us to increase yields and reduce costs. The role of micropropagation has already been discussed early in the Conference. I consider it has a positive long-term role for our industry, although inevitably we will misuse the technique and almost certainly, it will be blamed for over-production at some stage.

Mycorrhiza offers exciting potential for accelerated growing and increased yields.

Biological control is already being used with good success in the glasshouse industry and, no doubt, its potential will become greater in our industry as we get near to the monotype of cropping of the glasshouse industry. Behaviour controlling chemicals (BCCs), which are those subtle, volatile chemicals which insects produce themselves and use to communicate alarm, food supplies, or sex. Rothamsted Research Station is actively involved in this work and is already playing its part in the control of codling moth in orchards and pea moth in vining pea.

The Use of New Equipment. No doubt new equipment will be developed which will continue to reduce the amount of manpower required in labour intensive areas. New materials will no doubt enable us to exploit the potential for further energy saving by increase of double glazing, etc. Alternative sources of energy must be exploited as alternatives to oil and one assumes that in the relatively near future, solar energy will be much more economically used.

Improvements in Management — Business Equipment & Communications. During the past decade, training has become a regular part of the nursery scene; there is, of course, still much greater potential in training and one can only see its role increasing. A few of us are already gaining the benefits of computers in stock control and production planning. They will inevitably continue to play their role. Probably the major

changes in the next ten years will be in communications which will enable us to speed up order processing and shorten delivery delays.

Stricter environmental control will inevitably push up our growing costs and we must face up to the fact that in the future we will be expected to treat effluent and reduce the nitrogen that is being poured into our water courses.

Changes in Propagation Techniques. My impression is that our approach to propagation is polarising; on the one hand some of us are increasing the use of simple methods of propagation for mass production of cheaper plants, while at the other end of the spectrum, the use of micropropagation demands more precision and strict environmental control.

In this country, we are at last acknowledging the role of mother plants in not only improving the health status and yields of our crops but also in reducing cost of collection of cuttings. In recent years, we have also begun to realise the folly of poor grading at the liner stage and the trend of using larger, well finished liners will continue to increase the resulting improvement of the finished plant.

Introduction of New Plants. The scope for the introduction of new plants and improved cultivars is still immense. Micropropagation will probably facilitate the re-introduction of a number of difficult to multiply plants.

Repeating one of my earlier comments, the future of the industry is indeed good; it will be up to the industry whether we take advantage of the situation, by attaching significant importance to the effect of supply and demand and avoiding the temptation of over-production.

CUTTINGS FROM CONIFEROUS SPECIES — TYPES AND ROOTING FOR CONTAINERS

BOJIN BOGDANOV
Higher Institute of Forestry Engineering
Sofia, Bulgaria

In Bulgaria our current studies with vegetative propagation of conifers are based on an examination of the following factors: (1) rooting potential and plant form as affected by the maturity of the mother plant; (2) seasonal physiological and anatomic features of the cutting as affecting quantity and

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speed of rooting; (3) selection of suitable types of cuttings to reduce the production time of pot-grown liners; (4) development of equipment to provide suitable regimes for rooting cuttings without the use of heat; and (5) grafting in the open to produce conifers for landscaping and seed orchards.

It is impossible to discuss all these aspects thoroughly. The third will be covered here, with reference to the others where applicable.

The studies carried out confirm that the life and regenerative potential of trees produced from rooted cuttings are closely related to the age of the mother tree as well as the position in the crown (upper portion) of the tree from which they are collected. Cuttings taken from the highest positions in the crown of the mother tree will reach the reproductive growth phase more quickly than those from lower portions. In this case vegetative growth is reduced. The plants form cones, which is a sign of their advanced maturity, and they will not be long lived.

For example, young rooted cuttings of *Thuja occidentalis* L., and some of its forms, when collected from old mother trees, produce cones in the nursery and remain dwarf. Because of this it is necessary to select forms which possess positive decorative qualities from the progeny of coniferous species. It is preferable if the selected plants are used only once for propagation during the juvenile phase (i.e. under 15 years). These will provide rejuvenated stock plants.

Experimentally, it is established that the optimum stage for rooting the cuttings is closely related to their carbohydrate supplies and the presence of young tissue with active cell growth. Physiologically, this stage is characterised by the predominance of reducing sugars over the quantity of starch (as defined by the Hagedorn-Jensens method, modified and improved by Blich, Sandstedt, and Popoff). Anatomically, this coincides with the time just prior to summer wood formation.

The effect of the above factors on the rooting process is illustrated with experimental results obtained in rooting cuttings of *Picea excelsa* Link. The data from this species must be accepted as quite indicative because of the difficulty of rooting cuttings of this genus compared to species and forms in the Cupressaceae family.

Preliminary studies have determined the type of cutting which will root, i.e. its age and length. These studies showed that good practical results can be obtained with two types of cuttings — those made from one-year-old shoots, and those having a basal portion of two-year-old wood (Figure 1). They

are collected from trees and seedlings of *Picea abies* (L) Kanst. (Syn.: *Picea excelsa* (Lam.) Link) of varying ages. From 12-year-old seedlings all good shoots are taken, while from older trees cuttings are taken only from the top of the crown. Their ability to root at different times of the year has been examined.

Figure 1. *Picea abies* cuttings. *Above*. Type B, with 2-year old basal section. *Below*. Type A, one-year-old shoots.

Rooting is carried out in cold frames using a medium of washed river sand over layers of compost and drainage material. A suitable regime for rooting can be maintained in such a frame for a maximum of 7½ months a year. The average temperature is from 20° to 25°C, with humidity over 80%. The experimental treatments include hormone-stimulated cuttings with two controls — wet and dry. Hormone treatments consisted of solutions of heteroauxin (IAA), indolebutyric acid (IBA), alphanapthaleneacetic acid (NAA) at suitable concentrations (Table 1). Duration of the treatment was 14 to 16 hours.

Summarised results from prolonged experiments show that *Picea abies* cuttings of both types root best when collected from early July to late August. Morphologically, this period begins when the shoot stops elongating and a terminal bud forms. The shoot's newly-formed bark is yellow-green in colour and is still soft. Cuttings collected in the second half of July give the highest rooting percentage. They have considerable resistance to desiccation since the young needles will absorb water and the cuttings remain turgid. Rooting is complete by the end of autumn but planting of the rooted cuttings in containers or in open ground can be done later.

From the data for *P. abies* in Table 1 it is seen that the percentage rooting of the two types of cuttings from seedlings up to 12 years of age is two to three times higher than that of the cuttings collected from older trees. This correlation is typical for both hormone-treated cuttings and the control. For example, in the wet control there was 74% rooting of Type A cuttings from young seedlings compared to 30% for those from old trees. With hormone treatment using IAA, rooting reached 78% for cuttings from young trees and 36% for those from old trees. The range is similar for cuttings with a 2 year base (Type B). In addition, cuttings from young seedlings develop stronger root systems and produce bigger plants.

It is important to understand that the rooting process for cuttings with a 2-year-old base is identical to that for cuttings from annual shoots. In addition to high rooting percentage for some variants, they develop a better root system which, even with the control 12-year-old seedlings, reached 150 cm in length. Root growth of Type B cuttings is equal to that of cuttings from 3 to 4 year old seedlings (Table 1). It can be seen that a practical advantage in using Type B cuttings is to shorten the production period for conifer liners by 2 to 3 years. This is particularly important for container production, as cuttings can be planted directly into a larger container, saving the costs of potting on.

The observations and data cited show that hormone treatments promote earlier rooting and a slight improvement in rooting percentage. This is seen more clearly with cuttings from older trees. Also treated cuttings develop a better root system. Irrespective of these advantages, hormones cannot overcome the age factor of the initial cutting material. On the other hand, good rooting of the control cuttings shows that rooting of conifer cuttings can be improved with hormones.

The second period of the year of practical importance for rooting cuttings in cold frames is from the end of February to the first half of April. In this period the annual shoots are typically mature morphologically and have good rooting potential. Taking the cuttings depends on the weather, but it must be done before growth starts. At this period there is a tendency for the cuttings to callus rather than to form roots. The top and lateral buds of the cuttings sprout quickly which retards root formation and growth. Rooting percentage at this period is 3 to 5% lower than in summer and the root system is weaker.

Table 1. Rooting of *Picea abies* cuttings collected in July or August. Results over a 5-year period (Nursery VLTI-Sofia).

Treatment	Percent rooted	No. of roots/ cutting	Mean root length (cm)	Mean shoot height (cm)
Type A cuttings from 3-year-old seedlings				
Dry control	80.0	10	90	11.4
Wet control	70.0	10	91	10.9
IAA 100 mg/1-16 h.	84.0	13	95	11.6
Type A cuttings from 6-year-old seedlings				
Dry control	78.0	7	56	12.3
Wet control	74.0	6	51	11.6
IAA 100 mg/1-16 h.	68.0	6	57	12.8
Type B cuttings from 6-year-old seedlings				
Dry control	86.0	8	65	18.6
Wet control	70.0	7	100	19.3
IAA 100 mg/1-16 h.	78.0	8	99	19.5
Type A cuttings from 12-year-old seedlings				
Dry control	70.6	8	145	17.2
Wet control-14 h.	63.2	8	133	16.5
IAA 150 mg/1-14 h.	65.3	11	130	15.0
IBA 30 mg/1-14 h.	68.3	10	145	16.5
NAA 30 mg/1-14 h.	67.3	10	154	16.0
Type B cuttings from 12-year-old seedlings				
Dry control	66.3	8	150	22.2
Wet control-14 h.	74.0	9	150	21.8
IAA 150 mg/1-14 h.	70.3	16	173	21.0
IBA 30 mg/1-14 h.	78.5	11	160	19.8
NAA 30 mg/1-14 h.	76.3	12	182	23.6
Type A cuttings from 70-80-year-old mother trees				
Dry control	32.4	3	92	11.9
Wet control-14 h.	29.8	3	96	—
IAA 150 mg/1-14 h.	36.3	8	115	12.0
IBA 30 mg/1-14 h.	34.6	5	103	10.8
NAA 30 mg/1-14 h.	35.2	5	124	12.3
Type B cuttings from 70-80-year-old mother trees				
Dry control	28.4	3	83	16.4
Wet control-14 h.	27.5	3	79	15.7
IAA 150 mg/1-14 h.	38.5	9	124	16.5
IBA 30 mg/1-14 h.	37.0	6	128	16.0
NAA 30 mg/1-14 h.	41.2	7	141	16.7
Type A cuttings from 120-130-year-old mother trees				
Dry control	29.6	3	84	10.6
Wet control-14 h.	28.3	3	78	11.2
IAA 150 mg/1-14 h.	32.4	7	116	12.0
Type B cuttings from 120-130-year-old mother trees				
Dry control	31.5	3	80	14.8
Wet control-14 h.	28.6	4	86	15.2
IAA 150 mg/1-14 h.	34.7	8	132	15.6

The least suitable period for taking cuttings is from early May to early July, when new growth is soft and cuttings quickly lose turgidity.

Successful rooting of autumn struck cuttings required greenhouse conditions with heat. Shoots at this time are becoming dormant and rooting at this period needs more detailed

study. Preliminary studies show, however, that acceptable rooting percentages can be obtained but require a longer rooting period. Considerable callus is formed at this period and an economic assessment is needed to determine whether it is feasible to propagate at this time.

Experimental and practical results show that our work with *Picea abies* has widespread interest. Forms representative of the genera *Thuja, Libocedrus. Cupressus, Juniperus*, and others have achieved a high percentage rooting (over 82%) from Type B cuttings when struck in early July. This shows that under Bulgarian conditions the anatomical and physiological factors are optimum for rooting Type B conifer cuttings at this period. Consequently they are being used for container production at the nursery at the Higher Institute of Forestry Engineering and will gradually be introduced in other ornamental nurseries in Bulgaria.

PROCEDURES AND PROBLEMS ASSOCIATED WITH THE TRANSFER OF TISSUE-CULTURED PLANTS

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Topline Nurseries started accepting tissue-cultured plants in spring, 1982, the main crop being *Zantedeschia*.

These were transferred, but not very successfully, mainly due to the fact that we did not have the right conditions. We had set up plastic humidity tents in an existing tunnel house. As this house was being used as a seed house with variable temperatures, it was obvious that a separate and permanent transfer house was needed.

At the end of 1982, a transfer house was built the size of our standard tunnel house — 1,000 sq. ft., covered and lined with a double skin of Fabricon polythene, with a concrete floor and the roof covered with 50% shade cloth. Inside there is a pull-over shade cloth which we use in the summer. A form of humidifier was used to maintain maximum humidity. We adapted an electrical chemical applicator by connecting a water supply to the vat and using a ball-cock; this ensured the vat would not run dry. The humidifier was on a time switch, which we adjusted according to the weather and inside temperatures, the ideal temperature being 20 to 25°C with 90 to 100% humidity. Both humidity and temperature are monitored continuously using a thermohygrograph.

With the onset of winter the two small heaters we had were not sufficient to maintain temperatures so a fan heater was installed. This has a seasonal summer/winter switch and for winter is set at 20°C. This has proved successful in keeping temperatures and humidity at a constant level. To extend light hours during the winter months (April to early September), lights were installed giving 16 hours of light per day.

This year the main crop we have transferred are *Zantedeschia*, and babacos *(Carica)*, as well as a few *Eucalyptus ficifolia*, with trials of *Caladium*.

ZANTEDESCHIA

Plants are received from the laboratory in plastic pots. These are plants which have been cut from sub-cultures — elongation stage plates — via the refrigerator. These plants need to be transferred immediately to avoid dehydration. Pots can be stored in a cool store if need be to hold them in limbo (maximum period of 1 week).

Prior to setting the pots are staged on a bench for 2 days with lids on. The lids are then removed and pots are left to sit for 1 or 2 days to allow plants to straighten and adjust to the ambient temperature. The plants are then removed from the agar and graded according to size and quality.

They are then washed under running lukewarm water to remove the agar with roots being trimmed at the same time. (By trimming roots we find the plants establish new ones quicker.) They are then submerged in a antibacterial solution for 10 minutes, drained, then set.

For setting we use plastic trays which have been washed and dipped in a anti-bacterial solution. The medium is 80% sieved propagation mix (which is 50:50 peat and pumice sand with minimal nutrients) and 20% perlite. Before using, the medium is drenched with a antibacterial solution plus Terrazole; left to drain, then roughed up for aeration. Plants are then set according to grade. We have three grades: strong plants, clump with stem, clump with budlets. We also set unrooted pieces from which the majority set roots.

Once set, plants are left on the middle bench for a week after which they start photosynthesising and form cuticle layers. At this stage they need minimal overhead watering. They are then moved to the side bench for more light for 5 days after which they will produce new roots and leaf growth.

During this 5 day period they are liquid-fed, which is continued until the plants are tubed. The plants are removed from the transfer house to another tunnel house to harden-off for another week before being tubed into 5 cm tubes for selling as liners. During the winter months this tunnel house has lights installed to extend the light hours. Also lower temperatures help the hardening-off process. After tubing, plants are kept in a tunnel house for another 10 days before being moved outside to a shaded cloche.

During the winter months the plants die down leaving a rhizome. This rhizome is removed from the medium, washed, dipped in a solution of fungicide (such as Benlate) and Terrazole, dried and dusted, then stored in muslin bags or boxes in which vermiculite or sphagnum moss has been added to prevent dehydration. These rhizomes are now ready for sale or for storing in a cool place for next year's sowing. Before sowing it is recommended to dip the rhizomes in gibberellic acid, 40 ppm. This stimulates growth of very small rhizomes and flowering in larger rhizomes.

During the past 2 years we have encountered many problems with *Zantedeschia*.

Media: We used vermiculite and perlite to start with. This proved successful for about 2 weeks then the plants stopped growing due to the fact that this medium contained no added nutrients. To overcome this we reset the plants into a propagation and perlite mix with the plants responding by producing new roots and leaf growth in about 8 to 10 days.

Bacterial decay: This was in the form of healthy plants collapsing overnight. We discovered this was caused by the fluctuation in temperature and humidity. It is also a seasonal problem. We have controlled this by regular use of an antibacterial solution and by installing the fan heater, thus keeping temperature constant.

Humidity: We constantly wet all benches and floors, along with capillary matting on all benches, to keep humidity at 90 to 100%. But with summer temperatures rising, keeping the moisture level in the air to achieve 90 to 100% humidity is proving a problem. To eliminate this problem we are planning to install a permanent fogging system.

BABACOS

Babaco plants are received from the laboratory in plastic pots which are placed on the side bench in a transfer house for 2 to 3 days to acclimatize the plants to the ambient temperatures. They are then taken out of the pots, washed under lukewarm water to remove the agar, with grading done at the same time. They are then submerged in lukewarm water to prevent any dehydration prior to setting. The plants are then set into a medium of sieved propagation mix (which is 50% peat and 50% pumice sand) and perlite (50/50), which is drenched with an antibacterial solution and Terrazole.

Once set, the plants are put in the transfer house under a fine mist for 4 to 5 days, then weaned from the mist by moving them further down the house. The plants are fed regularly with Wuxal applied by spraying, using a Cambrian bottle. They are also sprayed with Benlate to reduce *Botrytis*.

Once established, with visual root and leaf growth, they are moved to a side bench for hardening off. They stayed there for about a week before being moved to a tunnel house to harden off completely before being tubed up as a liner ready for sale. Babacos respond to liquid feeding, so once they have been tubed we give them weekly sprays of Wuxal to promote utmost growth.

Problems we have encountered with babacos are:

Media: We used vermiculite and perlite to begin with but after 10 days there was no response so we changed to a propa-

gation and perlite mix (50/50) with an immediate response in both root and leaf growth.

Desiccation of leaves: We experimented with taking lids off prior to setting but leaves became too dehydrated. To prevent dehydration after setting, the plants were put under a fine mist. We are also investigating a fogging system to combat this problem.

Roots susceptibility to chemicals: This may cause root burn and stunted growth. We use a weak concentration of a fungicide (Benlate) and Terrazole solution which seems to be adequate.

Leaf drop: Babaco plants are susceptible to any temperature, chemical, or fertilizer change; this causes leaf drop to occur rapidly which is detrimental to plant growth; we are still investigating this problem.

EUCALYPTUS

We have had limited success with *Eucalyptus ficifolia* doing many trials with different media, size of roots and plants prior to setting, and using various chemicals.

The main significance of the trials was that both root and plant size seemed to be a major factor for a successful transfer. The plants we had the most success with had roots 1.5 to 2 cm in length, with the actual plant being about 2 to 3 cm in height. We had the most success with our control trays which had no treatment. The medium we used was 50/50 sieved propagation mix and perlite. Trays used were washed and submerged in an antibacterial solution and then the medium was drenched with Benlate and Terrazole.

Once plants were set they were placed on the side bench for 5 days then gradually weaned off by being moved to a higher degree of light for the next 3 to 4 weeks, then moved to another tunnel house to harden off before being tubed up as a liner.

Problems with *Eucalyptus ficifolia* were mainly *Botrytis*. We controlled this by regular sprays of Benlate and Diathane (½ tsp each to 1 Cambrian spray bottle). Also we found by putting plants under mist we encouraged *Botrytis*, so to combat this we sprayed plants with water 4 to 5 times a day using a Cambrian spray bottle.

CONCLUSIONS

Overall, we have succeeded in transferring tissue-cultured plants successfully, maintaining an 80% plus survival rate. The main factor for success is to have the right conditions for

each kind of plant. To achieve this we hope to expand and have the right environment for each plant transferred.

Our main objective for the future is to offer the highest quality product to the New Zealand grower and meet the demands required for export. Tissue-cultured plants hold an exciting future and it is our intention to continue our research and selection so that we can offer the industry quality that will produce high returns.

USE OF *PINUS RADIATA* BARK: A FOUR-YEAR EXPERIENCE

GRAEME C. PLATT

Platt's Nursery
Albany

Processed *Pinus radiata* bark has now been available in New Zealand for over four years and, during this time, we have used it exclusively for all our production of a wide range of New Zealand native plants.

Prior to using pine bark, we had been using sawdust for a number of years and had established that wood waste was a satisfactory medium in which to grow plants. Our prime motive for using sawdust had been economics. Our local timber mill was delivering 12-metre loads to our nursery free of charge, with the exception of a minor freight charge. Our respect for wood waste soon increased far beyond economic considerations. Besides costing nothing, it was weed-free. Plants developed far superior roots, with little or no pathogenic damage — generally described as water-borne fungi — such as *Phytophthora*. However, the longer we used sawdust, the more problems we were having with non-pathogenic fungi, which rapidly decomposed the sawdust. The final blow was a fungi which only took a couple of weeks to decompose an 8-pint planter bag full of sawdust. It also produced an unpleasant odor, along with enough heat to cook the roots of the plants, which subsequently died.

In order to overcome this decomposition problem we decided to change to pine bark, which had proved more than satisfactory in small trials. We spent considerable time designing a machine which would pulverise bark into a potting mix in one operation. However, while we were still working on this design, we were approached by a soil company, who asked what the prospects were for pulverised pine bark as a peat substitute in horticulture. We responded enthusiastically, and the company, known as Granulated Bark, was set up.

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During this time, much discussion took place on what grade the bark should be. It was always my contention that the pulverised bark should be suitable for planting plants without any addition of sand or any other substance to alter its structure. From the very beginning, we planted into 100% bark with no fertilizer, placing the fertilizer on the top of the containers a couple of weeks after potting. This technique had two advantages:

(1) Pricking-out losses dropped off dramatically.

(2) It was useful to have the flexibility of being able to respond to the different nutritional requirements of each species.

We had discovered earlier that the biggest single reason for losses at pricking-out and potting-up was too much fertiliser in the potting mix. The big disadvantage in placing the fertiliser on the top of the container was that it was most desirable to do this just prior to a heavy rain, or during a heavy rain, and we never seemed to get enough heavy rain when we needed it.

After the Granulated Bark Co. installed a batch mixing plant we decided to have our fertiliser pre-mixed for two reasons:

(1) It eliminated one routine job from the work programme.

(2) The bark was often so dry we found it extremely difficult to wet. However, when water was added in the mixer, no further problems were encountered.

The most satisfying quality of bark is that it is impossible to waterlog and, in a container-growing nursery, this is of paramount importance. However, other growers claim that it is too free-draining. We would describe bark as a warm, living, organic medium, resembling in many ways the litter which is to be found on a mature forest floor. It is in this highly rich, organic litter that plants are always seen to be doing their best.

Iron deficiency became a chronic problem in the nursery after changing over to bark, as the tannin in the bark locks up iron. Therefore, fairly heavy applications of iron sulphate are desirable. We noted that if the bark was saturated with iron sulphate, it went black and, once black, the plants never again suffered from any iron deficiency. With this philosophy in mind (i.e., that the nutrients be locked up in the mix) — coupled with our knowledge of fertiliser toxicity — we decided that a potting mix should have most of its nutrients locked up. The nutrients then become available to the plant slowly, as the plant grows and requires it. We have now changed our

fertiliser regime accordingly and, where possible, slow-release nutrients are used.

Dolomite lime provides us with calcium and magnesium — serpentine-reverted superphosphate for phosphate, calcium, and magnesium. We have found fish meal a good biological decomposition starter and an excellent source of calcium phosphate and trace minerals. Potassium and sulphur are provided from potassium sulphate, zinc from zinc sulphate, copper from copper sulphate, boron from sodium borate, and manganese from manganese sulphate.

Nitrogen is the nutrient which causes us the most problems. We have found that the correct addition of nitrogen to a potting mix is no guarantee that a plant is getting the correct amount, or any at all. On hot days it disappears into space as a gas, and on wet days it is washed out by the heavy rain. We currently use three sources of nitrogen in the nursery — calcium ammonium nitrate or sulphate of ammonia for quick-release, and urea-formaldehyde as a slow-release nitrogen. These are added to the bark mix. However, we also add calcium ammonium nitrate, and sometimes calcium nitrate, to our irrigation water, when I see nitrogen deficiency appearing around the nursery. I am now of the opinion that a container nursery should permanently lace its irrigation water with nitrate — say calcium ammonium nitrate — in the correct proportions, to ensure nitrogen levels are satisfactorily maintained at all times. If the irrigation water has a correct level of nitrogen, the plants correspondingly maintain that level.

The pH of bark is very low — 3.8 to 4.3 were the figures we obtained during tests. This, we feel, is a tremendous advantage as it provides the necessary acidity to release the nutrients from the alkaline fertilisers. In spite of the early dire warnings from agricultural officials, academic workers, and my fellow nurserymen friends, about the chronic toxicity problems inherent in bark, we have found none. At times we have obtained bark that is still juicy-fresh from the trees; at other times it has been composted for months. We have found no major difference, as long as the fertiliser levels are correct. The only toxicity we ever encountered was with a batch that had caught fire with spontaneous combustion, and this extreme heat had created creosote and tars that had condensed in the cooler parts of the heap. These toxins did, in fact, burn some plants at potting up. However, it is fair to add that those plants, once recovered, were some of the best I have ever grown. It could also be that such substances as creosote could be useful in repelling pathogens. Pine bark is extremely prone

to spontaneous combustion so it should never be stored where it creates a danger to buildings and property.

Many New Zealand nurseries are now using radiata pine bark. A number of large Auckland nurseries are now using pine bark 100%, and enthusiastically extol its virtues. I have seen cuttings and seeds being propagated in it very satisfactorily. In conjunction with our experiences with pine bark, I can only say that we believe it to be an excellent growing medium, far superior to anything else we have used — subject to the addition of the correct nutrients for the crop being produced.

CONTAINER PRODUCTION OF ASPARAGUS SEEDLINGS

JOHN M. FOLLETT

Ruakura Soil and Plant Research Station
Private Bag, Hamilton

Interest in asparagus (*Asparagus officinalis*) growing has increased rapidly in New Zealand in the last few years. In the Waikato alone, the area in asparagus has grown from 16 hectares in 1978 to over 700 in 1982. This had led to an increasing demand by growers for planting material. Traditionally, the supply of asparagus plants has been met by growers or specialist nurserymen spring-sowing seed in a prepared nursery bed using a precision sower such as the Stanhay. Late in the following winter, the dormant crowns are lifted, usually with a chain potato digger. The crowns are dipped in fungicide then planted out in the field, often after several weeks in cold storage. Because the open pollinated cultivars are variable in both growth habit and yield, considerable effort has been directed towards the production of more uniform and potentially higher yielding hybrids. Unfortunately, hybrid seed is more expensive than seed from open pollinated cultivars. This need to make every seed count is one of the reasons there is now increasing interest in the container production of asparagus seedlings. Other advantages of using container-grown stock over crowns include a lower risk of disease, less planting shock, increased germination percentage, and greater planning and planting flexibility for the asparagus grower.

There are probably as many ways of producing asparagus seedlings as there are growers. The following is an outline of the methods generally used at Ruakura where production is mainly to provide plant material for research purposes.

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SEED GERMINATION

Generally three months is required from the time of sowing until the seedlings are ready for planting. For the usual October/November (spring) planting, seed is sown under glass in July/August (winter). Seed is treated with a suitable fungicidal dust (e.g., captan, benomyl or thiram), soaked in aerated water for 24 hours, then sown directly into containers at a depth of 5 to 10 mm. Because of the high viability of hybrid seed only one seed need be sown per container. The optimum temperature for germinating asparagus seed is between 25° and 30°C with germination below 20°C being very slow (7).

At Ruakura, after sowing the seed, the containers are placed on a hotbed under mist. Misting ensures relatively even watering, resulting in more even germination and later growth. The thermostat for the hotbed is set to supply heat when the temperature drops below 21°C. Temperatures in the glasshouse should then be kept above 16°C, with ventilation starting at 21 to 23°C (4). At Ruakura, the glasshouse is heated by fan-assisted electric heaters which switch on when the temperature drops below 17°C. The ventilation which is also fan-assisted is set to come on when the temperature reaches 25°C.

Initially, watering was carried out by a misting system controlled by an electronic timer. As the fungus disease, *Stemphylium*, soon became a problem, hand watering once a day was used as an alternative to try and keep the vegetation dry for as long as possible.

CONTAINERS

Several pot types readily available in New Zealand have been compared (2). It was found that the FH 508 paper pots and the Rootrainers (Fives) were the most suitable for raising asparagus seedlings. In Canterbury, seedlings have been produced in polystyrene trays while other nurserymen have tended to use Rootrainers. The Rootrainers have met with considerable success (5), while many growers have had problems removing seedlings intact from the polystyrene trays (3). K.J. Fisher (unpublished data) recommends that to allow unrestricted growth of the seedling, the container should be at least 7.5 cm deep with a cell volume of between 25 and 30 cm^3, and with a density in the glasshouse of approximately 1,000 plants/m^2.

We use the Ferdinand Rootrainer which forms a container 10 cm deep with 40 cm^3 capacity; however, the density at approximately 1,400 plants/m^2 is higher than that recommended by Fisher. Although the Ferdinand Rootrainer produces a smaller plant than the Fives Rootrainer (3), this is compensat-

ed for by the fact that there is production space for approximately 500 more seedlings/m^2.

POTTING MIXES

No work has yet been carried out in New Zealand on comparing the various potting mixes available. However, two mixes, loosely based on the U.C. potting mixes, are among those currently being used with reasonable success (Table 1). One is the standard compost used by Massey University (Fisher, pers. comm.), while the other is the U.K. Glasshouse Crop Research Institute (GCRI) compost used by the Levin Horticultural Research Centre (L.G. Tilbury, pers. comm.).

Table 1. Potting mixes and fertilizers used for growing asparagus seedlings.

Massey University mix (50:50 peat/sand)	G.C.R.I. mix (75:25 peat/sand)
Fertilizer/m^3	
1500 g Osmocote	2500 g Osmocote
1500 g superphosphate	1350 g superphosphate
1500 g lime	2030 g lime
3000 g dolomite lime	2030 g dolomite lime
plus trace elements	680 g potassium nitrate
	490 g calcium ammonium nitrate
	plus trace elements mix

At Ruakura, the GCRI mix has been used, with pumice being substituted for sand. One problem that has arisen at Ruakura from using peat and pumice in the potting mix is that the mix contains no mycorrhizal fungi. As asparagus grows much more quickly when inoculated with mycorrhizal fungi, it is important that this be achieved as soon as possible. Generally, inoculation would occur in the field after planting out. However, in areas where the soil has been sterilised (as has occurred at Ruakura) or where it is common practice to deep plough prior to planting and thus bury topsoil and mycorrhizal fungi out of reach of newly planted seedlings, inoculation may be delayed or not occur at all. Powell (6) recommends collecting soil from underneath a vigorous patch of clover (*Trifolium* spp.) and incorporating this into the peat/pumice mix. Fortunately, the mycorrhizal fungi are not host specific and the fungi associated with clover will readily form a symbiotic relationship with the asparagus. Approximately 50 g of soil inoculum per litre of potting mix is recommended. The addition of soil to the mix increases the buffering and cation exchange capacity of the potting mix but may also increase the risk of introducing disease.

SPRAYING SCHEDULE

As a general hygiene practice the glasshouses are routinely sprayed with fungicide once every 10 days and with the insecticide Attack (pirimiphos-methyl and permethrin) and the miticide, Plictran (cyhexatin), when necessary. Sumisclex (procymidone), Rovral (metalaxyl), and Benlate (benomyl) are the fungicides used, with these being sprayed alternately, so that each spray is used once every 30 days. Despite these fungicide applications, we have still had problems with infection and eventual death of some seedlings from the disease *Stemphyliuym* (needle blight). We have managed to control this by an additional spraying of Difolatan (captafol) once every 7 to 10 days.

If the seedlings have not been planted out before 3 months, we also apply a foliar application of Nitrophoska. This contains N, P, K, Mg, Mn, B, Cu, Zn, Mo, and Co, and is given once every 7 days until the plants leave the nursery.

HARDENING OFF

When the seedlings are about 20 cm high and have several upright stems they are hardened-off outside for at least two weeks. This is usually done under the protection of a shadehouse.

SEEDLING PERFORMANCE AFTER PLANTING

Seedling transplants have not yet been grown extensively in New Zealand and, of those crops that have been established, no production figures are available at this time. Overseas research comparing asparagus crown and seedling transplants have not been very enlightening, with results often being contradictory (1,8). The main advantage to the grower of planting containerised seedlings will probably be greater planning and planting flexibility rather than an increase in asparagus spear production.

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GLOMERELLA CINGULATA ON CAMELLIAS AND THE IMPLICATION FOR PLANT EXPORTS

A.J. McCULLY, A.F. RAINBOW,
GILLIAN LAUNDON, and J.J. SOTEROS

Plant Health and Diagnostic Station
Ministry of Agriculture and Fisheries
Levin

INTRODUCTION

In June, 1982, United Kingdom (UK) plant health authorities reported to New Zealand that many camellia plants imported from New Zealand over the previous few weeks were suffering from leaf blotch, leaf drop, stem dieback, and in extreme cases, death.

The causal organism was identified as *Glomerella cingulata* (Stone.) Spauld. and v. Schrenk (con. stat. *Colletotrichum gloeosporioides* Penz.). U.K. authorities contended that a new "camellia strain" of *G. cingulata* had been introduced from New Zealand with camellia plants and that this strain was capable of causing similar effects to that described by Ngo Huy Can, *et al.* (4) in USA.

Glomerella cingulata had not previously been recorded as causing disease of camellias in New Zealand, where it is generally regarded as a ubiquitous secondary pathogen commonly associated with tip dieback of plants (e.g. *Citrus* spp.) especially following winter injury, but important as a fruit rot organism (e.g. causing bitter rot of apples (3).

G. cingulata has been reported as a pathogen of camellia in USA (1) and Australia (2).

PATHOGENICITY TESTS

Field observations in UK had indicated that infection was prevalent on *Camellia* cvs. Donation and Debbie, although it was not confined to these cultivars. For this reason, *Camellia* cv. Donation was selected for use in the pathogenicity tests, which were undertaken as follows:

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Experiment 1. Six *G. cingulata* isolates were each tested for pathogenicity on five *Camellia* cv. Donation plants. Each test was undertaken at two temperatures: 15° and 25°C. Each plant was inoculated as follows:

(a) Leaves were wounded by stabbing with a scalpel (six wounds per leaf).

(b) A leaf was removed, leaving an exposed leaf scar.

(c) An unwounded leaf was inoculated.

(d) A stem was cut and a droplet of spore suspension placed in the cut.

Spore suspensions were prepared to provide a spore concentration of $0.5 \pm 0.1 \times 10^6$ spores per ml. All inoculated parts of the plant were covered with a spore suspension of the test isolate, applied with a brush. The following isolates were used:

82/1 — ex U.K. (taken from a N.Z.-grown *Camellia* sp.)
82/2 — ex U.K. (taken from a N.Z.-grown *Camellia* sp.)
82/3 — ex N.Z. *Camellia*
82/4 — ex N.Z. *Citrus*
82/5 — ex N.Z. *Syngonium*
82/6 — ex N.Z. *Macropiper*
82/7 — Control — inoculated with sterile distilled water

Following inoculation the plants were placed in mist cabinets for three days, and were then removed and placed in growth cabinets (12 h day/12 h night) at either 15° or 25°C, as appropriate.

Results are given in Table 1, based on observations after 35 days (9.11.82).

Table 1. Mean from inoculation of both 15° and 25°C treatments.

	Inoculated (leaf lesions)	Wounded leaf (leaf drop)	Unwounded (leaf infection)	Leaf scar (infection)	Wounded (stem infection)
82/1	Tce	−	−	−	−
82/2	+	+	−	+	+
82/3	+	+	−	+	+
82/4	−	−	−	−	−
82/5	+	+	−	+	+
82/6	−	−	−	−	−
82/7	−	−	−	−	−

+ = infection, or positive result
− = no infection, or negative result

No differences in infection occurred between experiments undertaken at 15°C and 25°C, except that infection was more rapid and more severe after 35 days at the higher temperature.

Clear differences in pathogenicity toward camellias was observed among isolates, especially the two U.K. isolates

which had both been isolated from New Zealand camellias in the U.K.

It was of interest to find that the *Syngonium* isolate (82/5) was equally pathogenic to camellia as some of the camellia isolates, although we were unable to demonstrate any pathogenicity toward *Syngonium*.

In no case did the infection on inoculated plants cause disease further than one node below the inoculation point. Later observations showed that plants subsequently produced healthy young growth from below previous wound infections.

Experiment 2. Eight *G. cingulata* isolates were each tested for pathogenicity on four *Camellia* cv. Donation, four *Photinia* cv. Red Robin, and four *Mahonia aquifolium* plants. This experiment was undertaken to test U.S.A. isolates, and to test U.K. concern that the so-called "Camellia strain" of *G. cingulata* was capable of infecting a range of hosts, including *Photinia* cv. Red Robin and *Mahonia aquifolium*, which are exported in significant numbers to the U.K.

Inoculations were undertaken as in Experiment 1, except that following inoculation, plants were maintained only at 25°C.

Isolates used were:

82/1)
82/2)
82/3)
As above
82/5)

82/6)
82/7)
82/8) ex U.S.A. (from camellia)(Baxter, pers. comm.)
82/9) ex U.S.A. (from camellia)(Baxter, pers. comm.)
82/10) ex U.S.A. (from camellia)(Baxter, pers. comm.)

Results are given in Table 2, based on observations after 29 days following inoculation.

Table 2. Mean results from inoculation.

	Camellia cv Donation						
	Wounded leaf						
	(Leaf lesions)	(Leaf drop)	Unwounded (leaf infection)	Leaf scar (infection)	Wounded (stem infection)	*Photinia* 'Red Robin'	*Mahonia aquifolium*
82/1	–	–	–	–	–	–	–
82/2	+	+	–	+	+	–	Tce
82/3	+	+	–	+	+	–	–
82/5	+	+	–	+	+	–	Tce
82/6	–	–	–	–	–	–	–
82/7	–	–	–	–	–	–	–
82/8	+	+	–	+	+	–	–
82/9	+	+	–	+	+	–	Tce
82/10	Tce	–	–	Tce	+	–	–

+ = infection, or positive result
– = no infection, or negative result

There was no evidence of pathogenicity of *G. cingulata* islates ex camellias shown to *Photinia* 'Red Robin' or *Mahonia aquifolium*.

The U.S.A. isolates were also shown to be more severe in infection than one U.K. isolate (82/2), or the New Zealand isolate (82/3); one U.S.A. isolate (82/10) produced less infection than isolates 82/2 and 82/3.

DISCUSSION

On the basis of the above results it is our view that a specific "Camellia strain" of *G. cingulata* does not exist. We consider that in any given range of isolates of *G. cingulata* from camellias and other hosts, some will cause disease in camellias under conditions of wounding or following physiological stress to plants such as occurs with handling, transplanting, and acclimatation of exported plants; others will not. Although some isolates of *G. cingulata* were capable of infecting camellias through wounds in these tests, there was no evidence to suggest that any of them could be regarded as a virulent pathogen, as inferred by Bertus (2), and Baxter and Plakidas (1).

FUNGICIDE TESTING AND RECOMMENDATIONS

A range of fungicides were tested for effect on germination and growth of three *G. cingulata* isolates in culture in order to develop recommendations for a spray and dip programme for control of the fungus.

Of the fungicides tested, prochloraz (Sportak 50 WP) showed little effect on depressing germination of conidia, but effectively suppressed mycelial growth of the test isolates at concentrations of 10 ppm and higher. Captafol (Difolatan) and dichlofluanid (Euparen), on the other hand, were effective in inhibiting conidial germination at concentrations of 10 ppm and higher. Chlorothalonil (Bravo) suppressed germination of conidia at all concentrations tested (1, 10 and 100 ppm).

Prochloraz has not yet been fully registered in New Zealand for use on ornamentals. Therefore, the spray and dip programme which was developed took into account the assumption that if prochloraz could be obtained, it would only be available in limited quantities for experimental purposes.

The spray/dip programme developed also took into consideration fungicides known to be effective against *Glomerella* on other hosts, and *in vitro* work (unpublished), on control of *Monochaetia karstenii*, another secondary fungus common on camellias.

On this basis, the following spray/dip programme was recommended for camellias and other known or likely hosts being grown for export:

From four months prior to export: (Spray every 10 days alternating with):

1. Benzimidazole e.g. benomyl (Benlate) plus dichlorfluanid, both at full recommended rates.
2. Captafol at full recommended rates.
   (Prochloraz may be substituted in this programme for either 1 or 2, if available).

(As captafol can cause irritation to eyes, nose, throat, and skin of sensitive people handling the fungicide or sprayed plants, captafol sprays should be discontinued at least six weeks prior to export, and benomyl plus dichlorfluanid — alternating with prochloraz if available — continued at 10 to 14 day intervals).

The final dip is to be undertaken in either:

1. Benzimidazole, plus dichlofluanid, both at full recommended rates.
   OR
2. Prochloraz, at 25 g.a.i. per 100 l water.

Exporters were also advised to exercise care in handling plants when removing from growing medium, dipping, and packing to avoid injury.

IMPLICATIONS FOR EXPORT

It has become obvious that on occasions a ubiquitous fungus of little or no consequence as a pathogen in one country, may become of concern on exported plants in the country of destination. This situation may be the result of plants being weakened by transplanting, shipment, and becoming re-acclimatised in the country of destination, especially if this is in the opposite hemisphere. In this respect the physiology of the plants may also be affected, as observations by exporters indicate the air-freighted plants appear to be more suscepitble to *Glomerella* infection than sea-freighted plants retained in cool containers.

New Zealand must be prepared to undertake research to develop control measures where required to ensure that exported plants are of the highest quality and are free from pests and diseases in order to maintain continued acceptance of plant products in overseas markets.

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THE INTRODUCTION TO NEW ZEALAND OF ELMS RESISTANT TO DUTCH ELM DISEASE

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Elms (*Ulmus* spp.) are hardy deciduous trees common throughout the northern hemisphere. They are used both for timber and amenity plantings and for centuries they have been predominant in the European countryside in hedgerows, fields, and wooded areas. Their use most pertinent to New Zealanders is in the urban environment where they are used in street plantings and parks and are frequently seen in the larger home garden. This, however, could change in New Zealand as it has in Europe, the United States, and Canada with the advent of Dutch elm disease (DED), if this dreaded fungus disease ever reaches this country.

HISTORICAL BACKGROUND

There has been two major outbreaks of DED in the northern hemisphere. The disease was first identified in western Europe in 1918 by Dutch scientists — hence the name Dutch Elm Disease. In 1927 it was found in southern England where it caused the deaths of many elms. The epidemic reached its peak about 1936 and then declined with fewer trees being infected and the symptoms becoming less severe. Europe was not alone with its problems, as in 1930 the disease was also identified in the U.S.A. where it was reducing the American elm population.

In Europe, DED appeared to be controllable until the late 1960s when it became obvious that there was another epidemic in England and that the causal fungus was far more virulent than that which had previously infected the elm tree population. Research showed that the second epidemic had been caused by a more aggressive strain of the original fungus and

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that it had probably been carried on unbarked elm logs imported from Canada. Since 1970 over 10 million elms in England and over 40 million in the U.S.A. have died.

LIFECYCLE AND SPREAD OF THE DISEASE

DED is caused by the fungus, *Ceratocystis ulmi*. The disease is carried from dead and dying elms to healthy trees by the elm bark beetles, *Scolytus scolytus*, and *Scolytus multistriatus*.

Elm trees which have recently died or are dying from the diseases are a breeding site for mature bark beetles. The beetles are attracted by pheromones given off by the tree and by the beetles already present on the tree. Both the adult beetles and the larvae tunnel characteristic insect galleries under the bark. Hyphae produced by the fungus grow through the bark and sporulate in the galleries. The spores become attached to the bristly hairs on the body and legs of the young beetles and are carried with them when they emerge in the spring. The beetles will fly or are carried by the wind to healthy elms where they will feed (maturation feeding) in the crotches of the twigs in the crown. The spores of the fungus carried by the beetle can then enter the tree through these feeding wounds. The spores develop in the woody tissue and are transported through the tree in the vascular system (Figure 1).

It is the defense reaction of the tree to the fungus in the vascular system which first make it obvious that the tree is infected with DED. The presence of the fungus stimulates the host tree to produce gummy deposits which clog the vascular tissue, leading to wilting and yellowing of the leaves, the first symptoms of the disease. Water is stopped in its passage up the tree and the crown wilts and dies. The gummy deposits in the vessels help in the identification of the disease. On stripping the bark off the twigs or cutting across their stem, brown streaks or spots can be seen in the outermost annual ring. The disease cycle is completed as the tree is weakened by the disease and becomes a breeding site for the beetles.

The disease is also spread by the tree itself. When the roots of adjacent healthy and diseased trees meet, the roots graft together and the sap intermingles, carrying the fungus from one tree to another, thus spreading the disease. Disease transmission via the roots is the predominant way in which the disease is spread in hedgerows in England.

Man cannot be ignored as an agent in disease transmission as he has been responsible for spreading the disease first between Europe and the U.S.A. and then returning the more virulent strain to Europe. As well as bearing this responsibil-

ity, man has moved infected timber within most countries where the disease occurs. Infested beetles within the timber emerge at their new location and infect the healthy trees in the area. There is also evidence that the beetles can emerge during transport of infected logs and new outbreaks have been found associated with major transport routes.

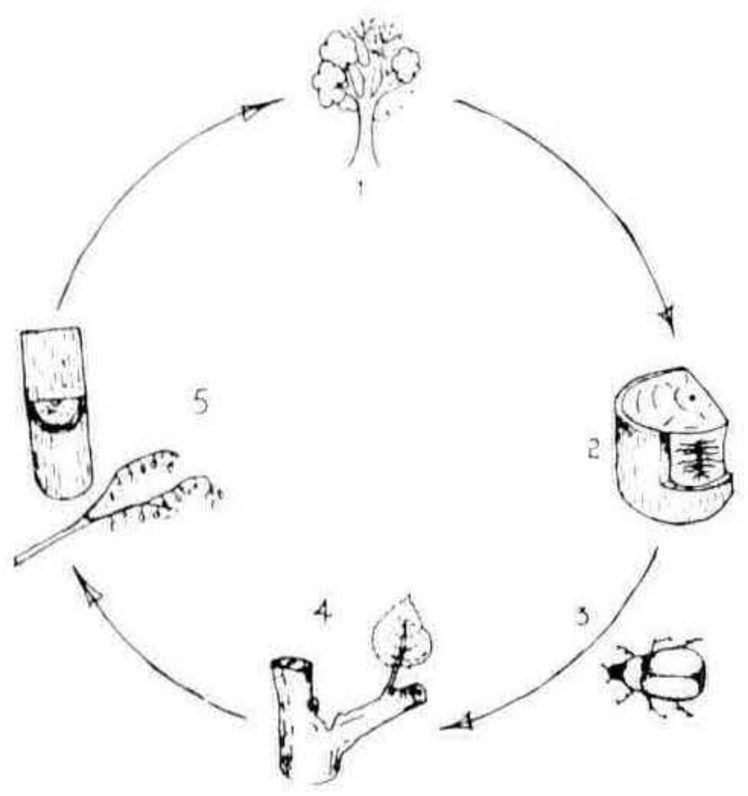

Figure 1. Life cycle and spread of the disease.
1. Trees weakened by the disease become breeding sites for beetles.
2. The adult beetle and larvae tunnel characteristic insect galleries under the bark.
3. Adults emerge in the spring and early summer from the bark of dead and dying elms, carrying spores of the fungus.
4. The beetles feed in the twig crotches of healthy trees and introduce fungal spores into the tree.
5. Infected parts wilt and diseased twigs show characteristic dark spots or streaks.

CONTROL

When the disease first broke out in England some control was achieved using a sanitation programme of felling the dead and diseased trees and destroying the bark. In this way the beetle larvae were killed before they could emerge as adults. When the disease was first discovered in the U.S.A. an effort was made to eradicate it using this sanitation programme. The programme was very successful up until the beginning of the second world war when manpower and funds were directed into the war and the attempt to eradicate the disease failed.

The insecticide DDT was also used as a method of control in the U.S.A. The idea was to spray the healthy trees with DDT to kill the beetles before they could introduce the disease to the tree. This reduced the number of infected trees but it also killed the wild life in the trees and surrounding vegetation and the programme was stopped. A less persistent chemical — methoxychlor (Marlate) — is now recommended. The healthy trees are sprayed in late winter and early summer to

kill the young beetles as they come to the trees to feed. Seasonal protection can also be given by injecting the trunks with the fungicides, carbendazin hydrochloride (Lignason), and benomyl (Benlate) which spread upwards in the tree with the rising sap.

A current method of controlling the spread of the disease via the roots of infected trees is to inject a soil sterilant, metham sodium, into the soil where the roots of elms could meet and exchange the disease. The chemical kills only tree roots that may try to grow through the treated soil and the trees are effectively isolated from each other.

ELMS RESISTANT TO DED

An alternative to control and prevention of the spread of the disease is to breed and select elms resistant to DED. A breeding programme began in Holland soon after the disease was first identified. The first resistant cultivars were released in 1936 but were not successful as they were susceptible to other diseases and lacked vigour. Two further clones were released in Holland in 1960. They are:

Ulmus × *hollandica* 'Commelin' — described as a fast-growing elm of moderate resistance to diseases and wind and suited for rural plantings, and

Ulmus × *hollandica* 'Groeneveld' — a slower-growing elm, with a rather dense crown, suited to the urban situation.

Both 'Commelin' and 'Groeneveld' were widely planted in Holland and small numbers were also introduced into other European countries including Britain. Late in the 1960s it became obvious that, in particular, the clone 'Commelin' was susceptible to the aggressive new strain of the fungus.

Previous to the new outbreak, the Dutch had been using European elms in their breeding programme. With the outbreak of the new aggressive strain of DED, the Himalayan elm, *U. wallichiana* was included in the parentage of new hybrids. The new breeding programme resulted in the selection of three clones which showed considerable resistance. The three clones were released in 1975 as: 'Dodoens', which has the appearance of a vigorous Exeter elm (*U. glabra* 'Exoniensis'); 'Lobel', which is a fastigiate narrow-crowned tree with small leaves; and 'Plantyn', which is broader in the crown than 'Lobel' and has greyish-green leaves and twigs. All three clones have the same female parent, *U. glabra* 'Exoniensis' (Table 1).

Elm breeding programmes were also established at various research stations in the United States and Canada. Resistant

parents of Asiatic origin (*U. pumila*, *U. davidiana* var. *japonica*), resistant cultivars from Holland, and *U. glabra* clones have been used in the American programmes to yield a number of resistant elms.

Two of the most commonly planted clones are *Ulmus* 'Sapporo Autumn Gold', of good vigour, disease resistance and ornamental value; and *U.* 'Urban'. Other resistant clones recently released on an experimental scale are *U.* 'Recerta' and *U.* 'Regal' in the USA; 'Jacan' and *U.* 'Thomson' in Canada; and *U.* 'Clusius' in Holland.

Table 1. *Ulmus* cultivars resistant to Dutch elm disease.

Cultivar	*Parentage*	*Selected by*
Dutch cultivars released in 1960 (suspectible to aggressive strain DED).		
'Commelin'	*U. hollandica* 'Vegeta' × *U. carpinifolia*	Phytopathological Laboratory, Baarn, Holland (Dr. Went).
'Groeneveld'	*U. glabra* × *U. carpinifolia*	Ditto
Dutch cultivars released in 1975 (resistant to aggressive strain DED).		
'Dodoens'	Self pollinated from the hybrid *U. glabra* 'Exoniensis' × *U. wallichiana*	Forest Research Station Dorschkamp, Wageningen, Holland. (Dr. Heybroek).
'Lobel'	(*U. glabra* 'Exoniensis' × *U. wallichiana*) × *U. carpinifolia*	Ditto
'Plantyn'	(*U. glabra* 'Exoniensis' × *U. wallichiana*) × *U. carpinifolia*	Ditto
Resistant American cultivars (resistant to aggressive strain DED).		
'Urban'	(*U.* × *hollandica* 'Vegeta' × *U. carpinifolia*) × *U. pumila*	USDA Nursery Crops Research Laboratory, Delaware, Ohio. (Dr. Schreiber).
'Sapporo Autumn Gold'	*U. pumila* × *U. davidiana* var. *japonica* (Open pollinated seed from Botanical Garden, Sapporo, Japan).	Phytopathological Institute, University of Wisconsin (Prof. Smalley).

INTRODUCTION TO NEW ZEALAND OF ELMS RESISTANT TO DED

DED has not yet been found in New Zealand and there is no record of the elm bark beetle. The beetle, however, has been identified in Australia, and has been intercepted on several occasions in New Zealand.

The most common elms in New Zealand are *U. procera*, *U.* × *hollandica*, *U. glabra* 'Pendula' (weeping elm), *U. glabra* 'Van Houtte' (golden elm), *U. procera* 'Variegata', and the Chinese elm, *U. parvifolia*. Except for the latter these are all

susceptible to DED if the disease was ever to become established in New Zealand.

The Plant Materials Group at the Soil Conservation Centre, Aokautere, Ministry of Works and Development, imported 6 cultivars resistant to DED in 1978 and 1980. The trees' first growing season in New Zealand was in quarantine at the Plant Diseases Division, DSIR, Mt. Albert. Plants and cuttings of 'Dodoens', 'Groeneveld', 'Plantyn', 'Lobel', 'Sapporo Autumn Gold' and 'Urban' were released from quarantine to the Centre in June, 1979, and September, 1981. After lining out in the nursery for 12 months, investigations were made into the best methods of propagation.

PROPAGATION METHODS

Hardwood Cuttings: Hardwood cuttings, 25 cm long, were taken in September (spring) from the basal portion of one-year-old shoots. These base of the cuttings was dipped for 15 seconds in 1000 ppm indolebutryic acid (IBA) before setting into a peat: pumice (50:50 by volume) propagation medium in wooden containers. The containers were put in a cold frame with bottom heat and covered with glass and Sarlon shade cloth for six weeks. The frames were ventilated and hand watered daily. When the six weeks heat treatment was completed, the heating cables were turned off and the glass removed. The cuttings were left under shade in the cold frame until early December when the rooted cuttings were transplanted into a medium with fertilizer (Table 2) in planter bags.

Table 2. Medium plus added fertilizers for growing rooted cuttings.

Medium components		Fertilizers
50 l peat	15 g	potassium sulfate
10 l soil	300 g	superphosphate
20 l pumice	50 g	Osmocote (3-4 mth)
20 l perlite	100 g	Osmocote (8-9 mth)
	10.5 g	fritted trace elements
	200 g	hydrated lime
	300 g	dolomite lime

The percentage of cuttings which were rooted and could be transplanted were:

'Dodoens'	32%	'Groeneveld'	No cuttings made
'Lobel'	32%	'Sapporo Autumn Gold'	10%
'Plantyn'	8%	'Urban'	30%

Grafting: Hardwood material of 'Sapporo Autumn Gold' and 'Urban' was grafted. In September, *U. glabra* stock was

brought into the glasshouse and forced with warmth and light to come into leaf. Both whip and tongue and cleft grafts gave 100% success with both cultivars.

Softwood Cuttings: In March 1983 (autumn) the elms planted in the field came into a second flush of new growth. This new material was used for making softwood cuttings, each 15 cm long with the basal portion of the cutting semi-lignified. The cuttings were treated with Seradix 2 before setting in a 50:50 peat/pumice mix (by volume) in Hillson Root-Trainers. They were then placed under intermittent mist ensuring that the leaves did not desiccate. The rooted cuttings were bagged in May. Only a small number of cuttings were made of each cultivar but the results were promising and further trials will be made.

Root Cuttings: When the plants were lifted after their first growing season in the field, the thickest roots were used to make root cuttings.

The roots were washed thoroughly and cuttings 5 to 15 mm thick and 50 to 150 mm long were prepared. After preparation they were dipped into a weak solution of the fungicide, thiram, and the ends of the cuttings were sealed with Shell Grafting Matrix (a petroleum-based product containing captafol). The roots were placed on a layer of pumice in propagation trays, covered with damp sphagnum moss, and the trays placed on a heated bed under intermittent mist.

Two months later the roots of 'Dodoens' and 'Lobel' had produced shoots 50 to 80 mm long. The shoots were removed from the roots by cutting a small piece of root away with the shoot. (The wounds on the root were sealed with the Grafting matrix). The base of the shoot was dipped in Seradix 1, set in pumice and returned to the mist. Within a month the shoot had produced roots and could be removed from the mist and transferred to a potting medium containing fertiliser (Table 2).

Three months after the roots had first been placed under the mist, more shoots were produced from 'Dodoens' and 'Lobel' and the first shoots were taken from 'Plantyn' and 'Groeneveld'.

The percentage of shoots which rooted and could be bagged from those originally removed were: →

Dodoens	96%	Plantyn	72%
Lobel	54%	Groeneveld	46%

Tissue Culture: In 1981 a culture of *U. villosa*, a Himalayan small-leaved elm, relatively resistant to DED, was received from the Forest Research Station, Wageningen, Holland. Plant-

lets were successfully proliferated on a modified Murashige and Skoog medium.

'Dodoens', 'Lobel', 'Plantyn' and 'Groeneveld' were put into culture using the soft juvenile material from the shoots of the root cuttings. The material produced callus but a suitable medium for promoting proliferation was not found.

NEW ZEALAND QUARANTINE REGULATIONS

To prevent DED from entering New Zealand the Ministry of Agriculture and Fisheries has imposed strict quarantine regulations on the importation of elm material. Seed, rooted stock, or grafting material can only be introduced with a special import permit and the material needs to be quarantined for at least one growing season in the glasshouses of the Plant Diseases Division (DSIR) at Auckland.

Imported elm timber either sawn or as logs must have the bark removed and is inspected for insects at the port of entry by the New Zealand Forest Service.

SUMMARY

In view of the probability of DED reaching New Zealand and becoming established, there are two recommendations. Firstly, that the clones resistant to the disease be propagated and sold for amenity plantings and, secondly, that as new clones resistant to DED become available, they be introduced to New Zealand.

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SELECTION, DEVELOPMENT, AND PROPAGATION OF AUSTRALIAN NATIVE PLANTS

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Many Australian plants have been difficult to propagate and many still are in that category. I do not intend to tell you how to propagate all Australian plants, but rather how selection and development of different species have given way to better propagation results.

Australian native plants, like all other flora, have characteristics which enable us to distinguish them from their neighbours. Each species have variations in growth habit, flowering, soil tolerance and climatic range. In an endeavour to gauge these differences we are carrying out experiments with a true-blue Australian plant lover on Sid Cadwell's property 200 kms west of Sydney, situated in a very dry area having approximately 300 to 350 mm rain per year. Summer temperatures reach 40°F and winter temperatures are below 0°C.

Australian plants, such as grevilleas, have been collected from all over Australia. This collection has been done with field trips to all parts where careful selection of parent material, usually cuttings, is made. These cuttings are generally harvested in very early morning or late evening. They are recorded and packed in plastic bags with very little water. In most cases cuttings are wrapped first in clean newspaper, then packed in styrofoam boxes and air-freighted to their destination.

Propagation takes place at two situations, one under mist with bottom heat, and the other without any facilities except a small glasshouse with no equipment at all.

When the plants have reached tube size they are planted out in the field. Many grevilleas are planted together and, say callistemons in another area, all in close proximity to one another. Their start in life is rugged as very often they only receive the one watering at planting time. Water is in very short supply on this property; however the results are good. In fact, autumn and spring are perfect for the job.

Under these conditions a grevillea, say from the Northern Territory, grows up alongside one from Victoria, Western Australia, New South Wales, or Queensland. After two to three growing seasons quite strange things happen, because they would never have been grown near one another and now find

themselves in the same bed so to speak; spontaneous or natural hybrids occur as seedlings under the parent plants.

Most of the property is heavily timbered with *Eucalyptus rossii* and many native species surround these plantings. Growing on the fringe of these clearings thousands of seedlings can be found in the leaf mulch and litter of the bush.

In David Gordon's garden in Glen Morgan, Queensland, famous for native plants, at his peak 6 to 8 gardeners were employed looking after his collection covering some 200 acres. Dave Gordon's idea was to preserve pure species and he, in fact, removed many thousands of natural hybrids. *Grevillea* 'Robyn Gordon,' named after his daughter, was saved by his life-long friend, Sid Cadwell.

When plants are taken into cultivation from the wild and vegetative propagation takes place, one of two things are likely to happen. The first, of course, is an unconscious desire or selection pressure for individual clones which are often easier to propagate, and certain elimination of other members of the group. Many people believe that this leads to a risk of drastic reduction in the genetic viability of the species. Many plants are naturally out-crossing in the wild and are self-incompatible. Whilst this risk is recognised in our situation we aim to collect more vigorous selections for nursery production. This method of obtaining plants is very valuable for the propagator and, at the same time, is anathema to botanists and purists connected with Australian plants.

Many other selections of our flora have come about in this way; foremost among these are the Cadwell, Masons, Paynes, and Poorinda hybrids, Mervyn Hodge in Queensland and George Lullfitz in Western Australia.

Seeing how these plants came about we were encouranged to help support Sid Cadwell plant out as many species as possible and play the waiting game. Selections from these plantings were made and plants propagated and assessments made for flowering, growth, and suitability for container production. Plants must have attractive growth and flowers and must perform well over a wide climatic range. These plants have peculiar characteristics; for instance, many flowered beautifully but produced no seeds, *Grevillea* 'Robyn Gordon,' G. Mason's Hybrid Royal Mantel; and G. 'Superb,' to name a few.

At the start some of these plants proved difficult to propagate but after cuttings were harvested, plants grown, and cuttings taken off these plants and they, in turn, grown and cuttings taken from the 3rd generation, many plants became much easier to propagate.

These hybrid types, or straight out selections, whether they occur naturally or not, have much more vigour and their flowering is not only improved but often extended. Some, like G. 'Robyn Gordon' flower 8 to 9 months of the year. Others are prized for their foliage, especially in the florist trade. Three examples are *Grevillea longifolia*, *Grevillea asplenifolia*, *Grevillea hookeriana*, and *Grevillea johnsonii*. Some species of the Genus *Banksia* also fit this category.

World interest in many Australian species suitable for the floral trade is apparent. Long stems, individual flowers, and attractive foliage of some grevilleas like 'Misty Pink' and 'Sandra Gordon' are being improved in breeding and selection programmes in America, Israel, and Holland. Banksias ex Hawaii is a classic example.

The kangaroo paw (*Anigozanthos*), Western Australia's floral emblem, has been hybridised many times and most cultivars are available in tissue culture. There are forms for both the floral trade and the home gardener.

Many of the types of plants, i.e. the selections I have talked about, are available in their wild state. One of these is a beautiful ground cover, hanging basket, spill-over type plant from Western Australia, called *Dampiera diversifolia*, a compact plant with small leaves and suckering habit. It has brilliant blue flowers most of the year but are best from winter to the end of spring — our largest selling ground cover plant.

Australia being the size it is makes it impossible to keep wandering over it all of your life; however, as a member of I.P.P.S. I am privileged to travel to a different state each year for our annual meetings and visit many interesting growers and collectors of plant material. We try to visit somewhere each month as well as at Sid Cadwell's planting. But by placing all the selections in one area one can quite easily observe many thousands of plants from all over Australia.

The Banksia genera is worthy of mention as there is a form of the east coast *Banksia ericifolia* 'Port Wine' which has most striking red flowers borne on long stems mostly on the outside of the bush, ideal for the florist trade and prized as a cut flower. This plant was developed by Sid Cadwell. It responds well to cutting propagation, rooting readily from soft tip material. A recent development has produced a dwarf form suitable for small areas of the garden. All species of the *Banksia* and *Grevillea* genera are great for birds in the garden and this has helped in plant sales.

The waratah (*Telopea speciosissima*) is much valued for its flowers. Selections of this plant have been planted and many

of these are being grown from cuttings. This is a very expensive operation; waratahs do not produce material suitable for propagation at a very fast rate. However, if one wishes to have these plants for flower production then they had best choose vegetative propagation methods, especially for the white and pink waratah.

Many propagators choose to grow this plant from seed and I do not wish to knock them since I grow thousands from seed myself.

I am not familiar with the New Zealand native plants and have no knowledge as to how they would perform planted out under the conditions I have described. I suspect similar situations and results would occur. Certainly I have one plant at Dural in Australia which is a terrific seller — *Metrosideros thomasii;* this plant flowers for at least 6 months of the year and has a most attractive grey foliage, a two-tone grey on green.

A more recent development by the C.S.I.R.O. Forestry Research Unit, Canberra, has produced a whole new range of salt-tolerant river red gum *(Eucalyptus camaldulensis).* During this programme many crosses were made and resultant strains of highly ornamental *Eucalyptus* suitable for the nursery industry have been developed. They will be propagated from tissue culture or micropropagation methods.

Looking to the future for new plant material and production of propagation material, suitable and viable sources have to be maintained. One can never hope to cover all the material available and the different purposes for which it can be used. There are people interested enough to endeavour to improve or select from the stock already on the market, much of which I suspect has come from more than one parent plant.

Macadamia, the Queensland nut tree, *(Macadamia integrifolia)* is an example of selection and hybridising and has been based very much on the type of planting I have described. I do not deny some cultivars have been deliberately crossed and bred.

Plant propagators have real winners as the fields they service cover such wide markets, and new plants and improved forms with the right promotion are readily accepted.

Grevillae 'Mason's Hybrid,' re-named 'Ned Kelly,' was a real stick up. In fact, they doubled the price of this plant which had been around for a long time.

The indoor plant field and the material available from our rain forests is about to be discovered in real terms.

The flowering hoyas have been hybridised and spectacular plants are coming on the market. Native cissus have found their place in similar programmes all around the world. The interesting part about the hoyas is their ability to be propagated by tissue culture. This method builds up initial stocks and makes propagation by traditional means much easier and quicker after 3 or 4 generations of plants have been produced.

In our plantings we prefer very small tube size plants, planting in the autumn and early spring; they receive very little water, in fact most are only watered once at planting time. They are mulched with bush or leaf litter to conserve moisture.

Whilst the summers are very hot and winters severe the spontaneous sports or natural hybrids seem almost to thrive. In fact, one may well be led to believe that they are bred for the area in which they find themselves. Other observations show that these plants do well in most climates. Why this is so I am unable to answer other than to say if they are hybrids there is extra vigour. Growing enough plants for field and container production is still difficult. In the first place there can be many hybrids or selections to choose from. To make the selection early is like going to the races, one does not know which will be the favourite. Plants with fantastic foliage in the early stage of life may get you excited, only to find the flowers disappointing.

These hybrids, or spontaneous sports as some people refer to them, are not new to me. My first experience in propagating and choosing a new plant was with the Swane's Golden pencil pine; 15,600 odd seedlings later I was rewarded with 30 or so variegated and full-coloured parent plants. I selected five parent plants, which I know was wrong. I should have used just one parent.

One classic new form of ground cover grevillea developed in Victoria, similar to G. 'Robyn Gordon,' with spectacular flowers is about to come on the market. This plant will be readily acceptable and has become an easy plant to propagate.

What all of this work has led to, of course, is other standard propagation methods being used, such as approach grafting of grevilleas resulting in weeping standard trees with ready sales.

Prostanthera is grafted onto *Westringia* for difficult areas and soil types and *Phytophora* resistance. Selection of two carnivorous plants almost extinct until a few months ago has led to their propagation in tissue culture in order to preserve them. One of Western Australia's rarest wildflowers, the Won-

gan triggerplant *(Stylidium coroniforme)* is an example of what plant propagators can and are doing. Pitcher plant *(Sarracenia)* also from Western Australia, has proved to be a great novelty plant; it is also tissue-cultured. They both sell well in the nursery trade as novelties.

The need to change lines of plant material brings the plant propagator under pressure to keep coming up with plants of high quality and performance. Native plants are in this situation. The craze for selling these has been dampened by selling too many untried plants from different regions of Australia, with the customer finding them to be unsuccessful in his area. A selection of *Eutaxia obovata*, a small native shrub to about 1½ metres, has been promoted as 'Sunshine'. This plant is older than I am and has not sold well because it was grown from a poor form.

The following list contains some of the more prominent Australian selections and hybrids:

Grevillea 'Robyn Gordon' hybrid *(G. bipinnatifida* × *G. banksii)*

G. 'Sandra Gordon' *(G. ptereclifolia* × *G. sessilis)*

G. 'Misty Pink' Banksii × *G. sessilis*

G. 'Mason's Hybrid,' also known as 'Kentlyn Hybrid' and 'Ned Kelly'

G. 'Superb'

G. 'Boongala Spinebill' *(G. bipinnatifida* × *G. caleyi)*

G. 'Cadwell's Hybrid'

G. 'Side Cadwell'

G. 'Jessie Cadwell'

G. 'Ivanhoe' *(G. asplenifolia* × *G. caleyi)*

G. Royal Mantle *(G. laurifolia* × *G. willesii)*

Macadamia hybrids

Kangaroo Paws hybrids

Callistemon Captain Cook selection
Hanna Rae selection
Endeavour selection

All the Poorinda hybrids (there are more than 20)

Paynes *Thryptomene* selection

Hoyas — many new hybrids not yet on the market. For climbing indoor flowering plants, foremost is 'McGilveriana', with rich red flowers.

Chamelaucium uncinatum, geraldton wax flower, for cut flowers is grown in hundred acre lots in Israel. There are selections red, purple, white and pink. These are grown in Israel by Western Australia nurserymen.

The Australian nursery industry, in presenting its submission to the Australian Rural Adjustment Unit Workshop on Rural Research, listed no less than 13 areas of research for the nursery industry.

Number 1 on that list reads as follows:

> Plant breeding and selection of native flora in respect to decorative appeal and ease of culture.
>
> (This submission was presented by Bruce Owen French, Chief Executive Officer — Australian Nurserymen's Association in October, 1983).

Again, in the Department of Agronomy and Horticultural Science Report No. 9, 1980-81 Sydney, Professor M. Mullins reports on the development of the waratah. *Telopea speciosissima* forms have been collected from the wild and are being selected for desirable traits. In this same report other native plants are mentioned for use as cut flowers: *Clianthus*, *Isopogon*, *Pandorea*, *Persoonia*, *Verticordia*, *Grevillea* and the Christmas bells (*Blandfordia* spp.). The waratahs and *Blandfordia* are being studied for tissue culture propagation at Sydney University.

Directions for rooting cuttings of large-leaved grevilleas:

1. The material should be selected during the summer as the new growth starts to mature; however, the cuttings must still be soft.

2. Cuttings should be made about 20 cm in length and given a basal wound by removing a sliver of bark, about 2 cm in length, in order to expose the cambium.

3. Hormone treatment should contain IBA and NAA in approximately equal parts, applied at the rate of 2,000 ppm to 4,000 ppm, depending on the type of growth (we like to use powder, not liquid).

4. The rooting medium should be well drained, such as 25% peat and 75% perlite, although some of our natives strike well in plain sharp sand.

5. Bottom heat applied to the cuttings at 20°C is a general guide.

6. Misting should be carefully controlled in rooting many Australian plants and should not be used in excess. Fogging is a great advantage.

7. Reduction of leaf area for large-leaf type plants is available — i.e. remove approximately half the leaf area.

8. Collection of cutting material should not be done in the heat of the day and the material should not be stored too wet.

9. For small-leaved plants harder wood, as used in semi-hardwood cuttings, is advisable — e.g. callistemons and fine-leaf grevilleas.

10. All cutting material should be clean and come from prepared parent plants and dipped in sodium hypochlorite, 1% solution, and washed in clear water.

11. Individual tubes for hard to strike plants is an advantage and allows more air and space around the cutting.

PROPAGATION OF DECIDUOUS TREES BY HARDWOOD CUTTINGS IN HEATED BINS

M. RICHARDS

New Zealand Nursery Research Centre
Massey University
Palmerston North

Propagation of woody plants from hardwood cuttings planted directly into the field has been a traditional method of plant production; in fact it was probably the earliest method of cutting propagation. The number of plants which could be propagated in this way was limited and it was useful only for those plants which have a very high potential to form roots. Studies over the last 2 decades have changed the whole picture of propagation by winter cuttings. In general it has been shown that by using more sophisticated technology it is possible to produce a much wider range of plants in this way than was previously the case. In particular it has been demonstrated that suitable cuttings of most deciduous woody plants, given the correct treatment, will generally root in the so-called "winter period". Much of this work has been carried out with fruit tree rootstocks, but similar techniques are now being applied to many ornamental plants as well, and this will no doubt become more important over the years to come.

It is important to point out that this type of propagation requires a rather more sophisticated approach than the traditional one; there is much less room for error. Having said that, I would stress that it does not require anything which is beyond the resources of the competent propagator. Most of the

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problems which have been brought to our notice have come about through neglect of basic principles, often in a desire to cut corners. It is, therefore, these basic principles that I wish to stress.

Cutting Selection. It is important to have stock plants which show juvenile characteristics as a source of cutting material. This is generally achieved by a regular programme of heavy pruning each year. Cuttings from an area of the trunk close to the roots generally have the highest potential to root; unfortunately this reduces the number of cuttings which can be secured from a mother plant. East Malling Research Station has developed techniques for producing cuttings of apple and other species on hedges, which is a compromise between the ideal cutting and a reasonable number of cuttings per plant. We are looking at using a similar system with ornamentals. Setting up suitable mother plants takes several years; this could probably be shortened if juvenile material could be secured initially from a central source.

Timing. There are normally two periods at which cuttings of deciduous plants have a high potential to form roots:

(1). About the time of leaf fall in autumn or early winter, usually late April to early May in New Zealand.

(2). About 3 to 4 weeks before bud burst in spring. Since there is little yearly variation in the time of bud burst, selecting an appropriate time to select "spring" cuttings is less difficult than it might at first appear. This function of timing is linked to levels of growth regulator activity in the shoots, particularly to levels of IAA and certain phenolic co-factors (3,4,6). Between the "autumn" and "spring" flushes of these constituents their levels may be quite low and cuttings may have a very low potential to form roots.

Cutting Selection. Thicker, rather than thinner shoots appear to give the best results; this is almost certainly related to the quantity of carbohydrate reserves in the thicker cuttings. As a general guide, the base of the cutting should include the base of the shoot, usually the swollen basal area if possible. There are however, apparent exceptions; some liquidambers and magnolias appear to give best results when the apical end of the shoot is used. Setting up trials for a new species or cultivar should, therefore, include both basal and apical cuttings.

Preparation of the Cuttings. Greater care is needed in the preparation of these cuttings than is done with conventional winter cuttings. The base should be cut cleanly with a sharp knife. Where only the basal part of the shoot is to be used the shoots can be much longer than would normally be required.

This type of cutting can be much longer than we would normally use; at East Malling they generally use 60 cm cuttings for rootstocks. We have tried 60 cm cuttings of maples with good results. I believe that, in part, this may be due to the larger total storage of carbohydrate. Wounding is invariably of assistance in stimulating root formation. We have normally used the simple side wound, removing a slice of bark, and have found that double wounding can produce a two-sided root system, which leads to greater tree stability (1,2). Howard (5) found for the M 26 apple rootstock a 2 cm split in the stem is superior to the conventional side wound. Clearly this is an area worthy of further investigation.

Treatment with IBA can usually enhance root initiation, although excessive concentrations may inhibit root development. Liquid formulations, using a standardised quick-dip treatment, have generally given best results. Concentrations ranging from 1,000 to 5,000 ppm have been used, but obviously the optimum concentration needs to be determined for each individual situation.

Cutting Environment. This is one of the most critical areas of the operation. Generally difficult-to-root cuttings require a period of relatively warm temperature at the base to initiate roots. It is not desirable to have roots emerge at this stage, so the period of warm temperature treatment is relatively short, usually abut 21 days at 20°C. During this time the cutting needs a copious supply of oxygen at the base, and an adequate supply of water which can be absorbed if required. This is generally achieved, overseas, by using relatively deep bins, often about 30 cm deep, containing a peat/grit mixture, with a heating element. The thermostat that controls the heating is located about 15 cm below the medium surface. The bin is well insulated to give constant temperature in the rooting medium; the depth of medium ensures good drainage and hence aeration at the base of the cutting. The cuttings are planted 10 to 15 cm deep, very close together, since roots will not be developed at this stage. Air temperatures are kept cool, to discourage bud burst, probably an over-all temperature of less than 5°C would be desirable. There is a need to avoid low humidity, since this type of cutting can lose water through cuticular transpiration. There may be some problems in securing these conditions, at least in some areas of New Zealand, and we are currently studying the effect of air temperature control by various means. After the period of warm temperature storage the cuttings are removed from the heated bin and held in polythene bags in cool stores until ready for planting.

After planting, bud burst will occur with the onset of rising temperatures and this should be accompanied by root emergence.

It may seem paradoxical that the aim is not to secure root emergence while the cuttings are in the heated bin, but there is a very good reason for this. Deciduous hardwood cuttings must exist on the store of carbohydrates as well as stored minerals. The warm temperatures at the base increase respiration in the cutting, hence reducing the store of carbohydrates. If roots emerge their growth further depletes the store of carbohydrates; if the roots are damaged during transplanting, there may not be sufficient carbohydrate available for both regrowth of the roots and the development of new leaves at bud burst. Failure to remove the cuttings from storage in heated conditions usually results in root emergence, followed by root death, and then death of the cutting. The symptoms are often mistaken for attacks of root decaying pathogens and lead to ineffective measures to combat the non-existent micro-organisms.

In cutting selection I draw attention to the need to have cuttings with a large reserve of stored carbohydrate. The control of the environment around the cutting needs to consist of the minimum amount of heated storage to initiate roots, followed by cool storage to conserve the remaining carbohydrate reserves until conditions are right for bud burst and root emergence.

While this is a desirable objective errors do occur, particularly with spring cuttings, where bud burst may occur before the completion of heated storage. At the New Zealand Nursery Research Center we have found a useful technique is to plant cuttings fairly thickly in containers of medium, which are then stood on a heated bed. If bud burst occurs during the period of heated storage the cuttings are left undisturbed when the temperature is reduced, until each has several leaves actively photosynthesising. At this stage the cuttings can be potted without serious risk of loss due to carbohydrate depletion.

Much of the technology currently being used at NZNRC is based upon the technology used so successfully in Britain, particularly at East Malling Research Station. With the passing of time propagators in New Zealand will no doubt develop individual techniques to suit their particular conditions. I hope that the principles which I have outlined will be of some assistance to you in that process of development.

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BULBS FOR THE FUTURE

TERRY HATCH

Joy Plants

R.D. No. 2, Pukekohe East

Much work has been done collecting and growing bulbs, corms, and tubers of all kinds. The work of raising hybrids from these plants in many cases has progressed slowly and much material has been lost over the years. Hybrids of the smaller scented species gladiolus are a case in point.

Raising hybrids of these types of plant takes many years as each generation may require 4 to 12 years to flower from seeds. Many of the bulb breeders I have met are in the older age bracket, 70 years or more, and many of them are amateurs; much of their work never gets into circulation and disappears when they pass on.

As this is such a vast subject, I shall discuss just two plants that have been studied and are now at the point of commercial production with the advent of micropropagation.

ZANTEDESCHIA SPECIES AND HYBRIDS (CALLA)

These now come in many colours — reds, violets, pinks, yellows, and all shades in between. There is still much opportunity for breeding, however, and following are some specifications for selection:-

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1. *As cut flowers*

Plants must be free-flowering in open ground, tough, hardy, and disease resistant.

Colour — Attractive under artificial light and in demand by consumers. Clear, intense colours without the basal blotch. My own preference is for pastels, but the orange and reds are popular and a good blue would be useful.

Flower shape — Sculptured, even, traditional, or possibly more open flowers, provided they are easy to pack, with stems that are in proportion and do not detract from the flower; also lightweight for freighting — 60 to 70 cm are preferred at present for export to Japan and there should be a demand for small, medium, and large flowers in the future.

Vase life must be as long as possible — trials of vase life, weight, and packing are needed. And for the future, perhaps scented flowers and other novelty lines — we have some with golden edges on violet, but need more selection yet.

2. *Pot plants and small garden plants*

The total effect is important with as many flowers as possible, stem and leaves in proportion, the flowers standing clear of foliage; coloured leaves are a bonus, intensifying the effect (the leaf colours, i.e. orange or red variegation could result from gibberellic acid treatment).

Pot plants must be attractive under artificial light.

As garden plants, colour depends on customer preferences. At present they are yellow, orange, apricot, pink-salmon, scarlet, ice white with pale green tinge, also bicolours with the ability to flower over a long period without gibberellic acid treatment.

3. *Larger garden plants*

As for small garden plants but with larger flowers and leaves in proportion.

NERINE SPECIES AND HYBRIDS

We have some very good cultivars now in New Zealand, with potential for a large export market. Breeding can still be of great importance as there are many other traits that could be included, i.e.

1. Longer stems
2. Multiflowering bulbs — 2 or 3 stems per bulb thereby increasing cut per sq.m.

3. Other colours — better quality whites, yellows, lemons, golds and good blues. More candystripes in other colours.
4. Larger flowers that fold their heads well, all with free-flowering habit.
5. Spring-flowering types, or extended flowering.

The list is endless, and the market I feel, is unlimited for bulbs and flowers of nerines, although they still take time to reach flowering size.

There are many other plants of this type for climates such as ours which have had little work done on them and could be, in time, well worth growing: A few, for example, are:

Brunsvigia	*Sparaxis*
Haemanthus	*Ixia*
Ornithogalum	*Clivia*

TECHNICAL SESSIONS

Tuesday Morning, December 6, 1983

The thirty-third annual meeting of the Eastern Region of the International Plant Propagators' Society convened at 8:15 a.m. in the Constellation Ballrooms of the Hyatt-Regency Hotel, Inner-Harbor, Baltimore, Maryland.

PRESIDENT SHADOW: I would like to welcome everyone to the 33rd annual meeting of the Eastern Region of IPPS. We have a very informative program and I hope everyone has a very good stay. We have a distinguished guest with us today. He is president of the IPPS International Board, Charlie Parkerson. I would also like to welcome members of the Southern and Western Regions who are here. I will next introduce our program chairman, Leonard Stoltz.

LEONARD STOLTZ: I would just like to point out to you that this program is not put together by one person. The program chairperson needs your help. The help you give is very appreciated. I mention this to you for the future program chairpersons to come. I will now turn the program over to Kathleen Freeland who will moderate the first session.

WHAT IPPS HAS MEANT TO THE NURSERY INDUSTRY

HUGH STEAVENSON
Forrest Keeling Nursery
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How does the International Plant Propagators' Society relate to the American Association of Nurserymen (AAN)? For one thing, IPPS is an international association while AAN is a U.S. body with a close affiliation with Canada. AAN is an association of nursery *firms* while membership in IPPS is composed of *individuals* from the commercial field as well as from academia.

AAN, in addition, has broad concerns with business, management, government relations, nursery stock standards, marketing, public relations and educational services. AAN administers such allied groups as the Garden Centers of America, Horticultural Research Institute (HRI), National Association of Plant Patent Owners, the National Landscape Association, and the Wholesale Growers of America.

AAN, while obviously vitally dependent upon research and progress in plant propagation and culture, is structured to stimulate and encourage such progress rather than to directly

engage in such study and research. For example, the seed money provided through the Horticultural Research Institute is paying handsome dividends in providing needed technical information to the nursery industry. It can be said without reservation that members of the AAN look upon IPPS as a vital well-spring of data and information on better plant culture.

I might point out that state and regional nursery associations have much the same interests and emphasis. The power-house nursery trade shows are wholly devoted to marketing, not growing.

WHAT IS PLANT PROPAGATION?

The narrow interpretation entails putting roots on a cutting, budding and grafting, micropropagation, producing a seedling, or otherwise birthing a plant. But my enlarged Webster's Dictionary is not so restrictive. It defines *propagate* as "to cause a plant or animal to multiply by process of natural reproduction from parent stock; to reproduce itself as a plant or animal does; to transmit hereditary features or elements to, or through, offspring; to cause to increase in number or amount; to multiply by any process of natural reproduction." I see nothing in these definitions that would restrict the term to the initiation of the plant.

Indeed, a review of IPPS Proceedings in later years finds many discussions pertaining to a broad range of production topics beyond the birth of the plant. This seems entirely logical and proper. There is no other forum so uniquely qualified to study and share plant culture information.

IPPS AND THE SUPPLY-DEMAND SITUATION

Certainly our Society has facilitated the production of a broad spectrum of plant species, types, cultivars, and clones. This is sort of a good-news bad-news situation. Our gardens, landscapes, orchards, vineyards and other areas of horticulture have reaped the reward from the experiments, observations, studies and reports of our members. The nursery industry, at this time in history, can be forgiven for having mixed feelings as to this facilitation of plant production.

I recall, a number of years ago, when a rather elaborate prank was concocted by some of our more exuberant members. Leslie Hancock, rest his soul, had been repeatedly describing with glowing enthusiasm his burlap cloud method for rooting softwood cuttings. It was to Leslie, and others caught up in the fervor, a limitless means of mass producing a broad range of woody plants. Our pranksters drafted a fake telegram

from AAN headquarters urging immediate cessation of Hancock's process lest the country be flooded with surplus stock.

Today the joke wouldn't be quite so funny. From tropicals to *Taxus* there is today scarcely a category of plants not in overproduction, or under-consumption, if you will. The resulting shake-up in the nursery industry has been and continues to be profound. We see jarring examples of old, established firms going bankrupt, or seeking refuge in Chapter 11. Many more are simply fading from the picture. We see consolidation with major corporations taking over sizeable chunks of the industry while struggling for profitability as they do.

But examine this supply-demand situation. It isn't *knowledge* of propagation that has caused over-production. It has been investment decisions. From the smallest grower to major corporations, production of nursery crops had been generally profitable for most of the post-World War II period. Consumption of these products had been increasing. Growing of nursery stock has been an attractive enterprise. Few had the foresight to trim sales as the economic downturn coincided with the cornucopia of supply that hit the market.

IPPS AND CHALLENGES AHEAD

I don't pretend to have any kind of a crystal ball to foretell the future of our industry. But I am optimistic that the prudent operator, the good planner, and the capable manager can look down the road with confidence. I am placing my money where my mouth is and encouraging those at our nursery to proceed with a propagation program that will gradually increase our volume. I expect they will kick me out before many of the plants we are now starting reach market size. But a significant production nursery is seldom a one-generation affair.

I think the challenges we as a Society have today are to encourage *quality* rather than *quantity* and to foster good husbandry of resources rather than exploitive production. Indeed, I think that is the track we are on.

Here are a few examples of challenges we, as propagators or plant scientists, face to improve the quality of our product or our production practices.

In the fruit field virtually every type and cultivar needs a virus clean-up. The improvement in quality and productivity of plant and fruit is then often amazing. Quarantine regulations will almost force virus-free certification in the future. At our nursery we expect to have all grapevine production virus-indexed within a year and now our fruit tree understocks are grown from certified virus-free seed produced by us.

A propagation revolution is proceeding apace with shade and ornamental trees. Many of the foremost growers express the view that the classic methods of budding on seedlings will generally be replaced by clones on their own roots. This would immediately overcome the scion-stock incompatibility problem and will, at the same time, present a new set of as yet unanswered problems. Will own root trees possess a root-system resistant to wind-throw? Will they be as hardy as the replaced seedling stock? Will they have other satisfactory characteristics? William Flemer's classic article on the subject in the 1982 *Proceedings* (Vol. 32) reviews the situation in depth.

The need for improved timber types has long been recognized by foresters, and decades of work have been performed on selection, breeding, and propagation of superior types. Yet I think workers in this field would agree that the surface has little more than been scratched. As our timber resources continue to be depleted, greater emphasis on improved forest tree types and their propagation will be accentuated.

Even now in timber tree regeneration we often do not exercise simple methods that have been established as superior. For example, in our state of Missouri, the state nursery churns out hundreds of thousands of black walnut seedlings for planting by landowners. Yet it has been repeatedly demonstrated that black walnut trees regenerated by direct seeding grow-off much better than seedlings, which suffer a severe growth setback due to unavoidable stubbed-back roots.

Despite the voluminous work done with tissue culture, the early prospect that much or most woody plant propagation would be performed by micropropagation has not been realized. Obviously, we have a ways to go here.

Property owners in highly populated USDA Hardiness Zones 5 and 6 desire to have some of the broadleaf evergreens enjoyed by their more southern cousins. Time and again certain candidates have looked promising only to be blasted by a winter like that of 1981-82. Continued selection and testing is needed.

Another problem and challenge before us as propagators is to grow a tree in a container without developing a ruinous root circle or potbound condition. This problem is definitely more critical with deciduous trees than with usual conifers, broadleaved evergreens, ericaceous plants, shrubs and the like.

BRINGING HOME NEW TECHNIQUES

One of the great benefits of IPPS to the nursery industry is the opportunity to visit and inspect operations of other growers across the country and around the world. This picking of

brains and sharing of ideas is invaluable in keeping abreast of new developments and techniques. By way of illustration may I mention some practices we have brought home to our nursery.

There is nothing new about windbreaks and, indeed, we have been planting them for years. But when our Wayne Lovelace was so impressed with windbreak protection after inspecting nurseries in England and Scotland during the recent IPPS G.B.&I. meeting in Aberdeen, he has been installing windbreaks all over our place.

As many who have visited our nursery know, we have long used mulch culture rather than clean tillage. This involves the use of hundreds of truckloads of bark-sawdust mixture annually. With our hilly, highly erodable soils and climate characterized by frequent, intense thunderstorms a clean-tilled culture would be disastrous.

Even with our mulch culture and green manure rotation crops following each nursery crop, soil erosion is still a problem in such heavy rainfall periods as last winter and spring. Accordingly we are now testing companion grass crops with our tree and shrub seedlings — a concept made feasible by post-emergent herbicide techniques pioneered by other propagators. Most of our woody plant seed is sown in summer or fall for germination the following spring. We are now seeding such grass plants as oats or annual rye grass over the beds and in the paths between the raised beds as our tree and shrub seeds are sown.

Normally, oats will be killed when there is no snow cover and the temperature falls to 0°F. Annual rye grass and similar grasses will live through the winter. We anticipate no problem in taking out the grasses before our crop seeds germinate with either Roundup or Paraquat or with grass herbicides, such as Poast or Fusilade.

We have observed another benefit of a companion herbaceous growth prior to crop seed germination. A sawdust mulch tends to cake and crust due to fungal mycelium knitting the sawdust particles together. This crusting is difficult to break up and can be very deleterious to seedling emergence. The dead and decaying tops and roots of the companion crop appear to alleviate this problem.

Because of the increasing scarcity and skyrocketing cost of bark we have taken a leaf from the vegetable and strawberry growers visited on IPPS trips and have been testing plastic mulches for seedbeds and especially, transplant beds. The new photodegradable plastics, pioneered by Israel, look especially

promising. These deteriorate after specified periods, opening the beds to rainfall or irrigation and leave no mess to clean up. This year chrysanthemum plants planted through plastic were superior in color and growth to those grown with our standard mulch.

Yes, IPPS has indeed had a profound effect in improving nursery practices. But even greater challenges lie ahead.

PROPAGATION BY SOFTWOOD CUTTINGS FROM ROOT PIECES TO REINTRODUCE JUVENILITY IN A NEW DWARF ROOTSTOCK (OTTAWA 3)

ROBERT H. OSBORNE

Corn Hill Nursery Ltd.
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Abstract. Softwood cuttings of the dwarf apple rootstock *Malus* 'Ottawa 3' were successfully rooted using material obtained from shoots grown from root pieces of plants which were in an adult (fruiting) state. The data showed that the reversion of the material to a juvenile condition was directly related to the changes brought about in the root piece process. Rooting percentages were increased by using 0.8% IBA, wounding of the cutting bases, and using terminal cuttings.

INTRODUCTION

The use of size-controlling rootstocks in the apple industry has had a profound impact on the productivity of modern orchards. The Malling series of dwarf and semi-dwarf rootstocks has been the most important and readily available. However, in the province of New Brunswick, Canada, and in similar regions on the northerly limits of commercial apple production, problems with winter hardiness have hampered efforts to introduce these rootstocks. Complete or partial winterkill has kept production levels far below those which were initially expected, and the search for comparable but hardier dwarfing rootstocks has intensified.

One rootstock, introduced by Agriculture Canada, which seems to offer promise is 'Ottawa 3', a cross between Malling 9 and the hardy, semi-dwarf 'Robin' crabapple. Trees budded to 'Ottawa 3' will have an ultimate height of approximately 3 m, be exceptionally precocious and very productive (1). Semi-dwarf trees can be produced by using 'Ottawa 3' as an interstem between the desired cultivar and a hardy, well-anchored rootstock. The height of the tree can be adjusted by the length of the interstem piece (2).

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A problem associated with the propagation of 'Ottawa 3' is that it is a shy rooter in the conventional stool bed (3). Because it fruits at an extremely early age, most propagation material available is in an adult state. Cuttings from this material, both hardwood and softwood, are generally very difficult to root. Conditions such as these tend to frustrate propagators and 'Ottawa 3' has been slow to appear on the market.

The first plants of 'Ottawa 3' which we received were 6 heavily cut crowns with a few roots. Ordinarily we would have planted these out and hilled them up to induce the shoot bases to root; however, a chance reading of an article by Dr. S.H. Nelson of the University of Saskatchewan prompted me to try cuttings as a propagation method. Dr. Nelson had showed that the progressive buildup of fibrous tissue in the phloem of juvenile apple wood (in this case 'Ottawa 3') was directly associated with the loss of rootability in the mother plants. These fibers were acting as mechanical inhibitors to the rooting process. The juvenile material that Dr. Nelson had was the result of the original 'Ottawa 3' material being cut down to nearly ground level where the plant was most juvenile (5).

Rather than cut our crowns down to ground level, we chose a different approach. Knowing that plants in the genus *Malus* generally can be propagated by root pieces (4), we decided to take pieces of root and force shoot growth from them in the greenhouse. Virtually all of our root pieces produced strong shoots within a month. Using this material we then proceeded to test these shoots for rootability.

MATERIALS AND METHODS

A total of 10 crops were taken during 1982 and 1983. These experiments were designed to demonstrate: (1) The rootability of material taken from the shoots derived from root pieces versus the rootability of the control adult phase material; (2) the influence of various concentrations of IBA on rooting speed and strength; and (3) the effect of mechanical wounding on rooting.

Cuttings were taken from mother plants grown in 1 gal pots in the greenhouse in a medium of peat (or finely shredded bark) and soil (2:1, v/v). The mother plants were fed with a soluble 20-20-20 fertilizer every 20 days. Both terminal and basal cuttings with 2 to 4 leaves were taken.

We used both a polyethylene humidity tent and an open misting bench. The humidity tent was watered intermittently as temperature dictated. The misting bench was misted every 30 min for 15 sec except during extremely warm periods when

the cycle was shortened to every 15 min. No mist was applied at night.

Cuttings were placed in 2½ x 2½ x 4 in. plastic pots in three rooting media. The media used were: clean sand and sawdust (1:1, v/v), clean sand and peat (2:1, v/v), or washed 1 mm ground limestone rock and peat (6:1, v/v).

RESULTS

Juvenility Factor. Our first crop involved 50 cuttings from the shoots which we had grown from our root pieces (which we will refer to as the juvenile group). A control crop of 50 cuttings was taken off the plants from which we had taken the root pieces (the adult group). Forty-eight of the 50 juvenile cuttings rooted. None of the adult cuttings rooted. These cuttings were rooted in a humidity tent using a 0.8% IBA commercial talc preparation (Seradix #3).

Our original results were duplicated in our fifth crop when a control group of adult phase material was again used for comparison. After 20 days, 100% of the 384 juvenile phase cuttings had rooted with an average of 10 roots per cutting. Average root length was 2 cm with occasional roots to 5 cm. The 43 adult phase cuttings showed slight callusing with a few roots up to 1.5 cm long. After 2 months the ultimate survival rate of the juvenile material was 86% compared to 16% in the adult phase group. It should be noted that none of the adult phase plants survived the first winter, whereas losses in the juvenile group were less than 4%.

IBA Concentration and Its Effects on Rooting. After our initial experiments had established the ease with which cuttings rooted when taken from the root piece material, we experimented with various concentrations of IBA using commercially available talc preparations. We prepared 261 2-leaf cuttings using material taken from the previous crops. The results were as follows (Table 1).

Table 1. Percentage of rooted cuttings at 20 day inspection

IBA concentration	Percentage of cuttings rooted
Control (no hormone)	0
0.1% (Seradix #1)	0
0.3% (Seradix #2)	5
0.8% (Seradix #3)	61

Ultimate survival of the cuttings treated with 0.8% IBA was nearly 100%. Survival of cuttings treated with the lower concentrations was very low.

We felt that higher concentrations of IBA using pure crystals suspended in an alcohol/water solution might be advantageous. In our sixth crop 1422 cuttings were dipped for 5 sec in various concentrations of IBA. The high concentrations severely burned the soft wood and gave low percentages of rooting. Only the control group, which used a 0.8% talc preparation, had an acceptable rooting percentage (Table 2).

Table 2. Percentage of successfully rooted cuttings.

IBA concentration	Percent rooted
20,000 ppm	5
16,000 ppm	14
12,000 ppm	22
0.8 % IBA (8,000 ppm) in talc	96

It is possible that concentrations in the 10,000 ppm range used for a 2 to 3 sec dip might prove useful, but we feel that the high percentages obtained by using readily available commercial talc preparations makes their use preferable.

Wounding of the Cutting Bases. The effect of wounding the bases of the cuttings was investigated. It was found that wounding was conducive to more rapid rooting and that wounded cuttings had a greater number of roots. In our third crop, it was found that after 20 days 91% of those wounded had at least 1 root over 2 cm in length. This compared to 77% for those which had not received wounds.

Terminal vs. Basal Cuttings. Although we have rooted cuttings taken from the basal portion of shoots, we have shown that terminal cuttings have a considerably higher success rate due to their ability to continue growth during and immediately after rooting. This ability becomes particularly important as the photoperiod shortens making it difficult to force the dormant buds on basal cuttings into active growth so that the cuttings can proceed into dormancy in a healthy, hardy condition. This, of course, reduces the number of cuttings that can be taken from the mother plants. In our opinion, however, only terminal cuttings should be used.

Propagation Chambers. Successful crops of cuttings were raised both under mist and in a polyethylene humidity chamber. We definitely favor the humidity chamber. Our best results occurred in Crop #4 using a high walled polyethylene tent suspended over a greenhouse bench. We feel the presence of moisture in the form of humidity at 100% rather than in the form of a heavier film of water on the leaves helps the cuttings retain their leaves without leaching of nutrients. Our misted

crops tended to lose their leaves and recovery was much slower and losses higher.

Rooting Medium. We continually decreased the quantity of water retentive materials in our rooting medium. At present, we feel a medium of 6 parts coarse sand to 1 part peat (or its equivalent) provides a well-drained medium with enough water retention to hold moisture between waterings. Similar results could probably be obtained with comparable mixes using materials such as perlite and peat.

DISCUSSION

It is our feeling that use of the techniques described in this paper for inducing juvenility in 'Ottawa 3' could provide a viable alternative to producing rootstocks from more conventional methods.

Such techniques might also be applied to the production of certain apple cultivars on their own roots. We intend to force root growth on the stems of grafted whips of ornamental crabs and spur or genetically dwarfish cultivars. Once we obtain root pieces we will use the shoots forced from these to begin cutting production.

Once the initial bulking of juvenile material has taken place, we believe this method would produce uniform trees of predictable height and habit, free of incompatibility related problems. In addition, many problems associated with unsterile field conditions could be avoided.

Although the success of our methods may vary with the cultivar in question, we intend to pursue the use of this technique in our fruit tree production and we urge others to try these methods and hopefully confirm our results.

Acknowledgement. We would like to express our deep appreciation to the National Research Council of Canada whose funds have allowed us to carry on this research.

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LEN STOLTZ: Usually quick-dips give more uniform rooting than powders. I would urge that you not give up on quick-dips. With the soft cuttings you are using I would recommend that you start at 2,000 ppm.

CHARLIE PARKERSON: We think that the injury problem is related to the alcohol used to dissolve the IBA. We have changed to the potassium salt and cut with water.

RALPH SHUGERT: I would recommend lower rates of IBA/NAA because of the soft condition of your wood.

OUTDOOR ROOTING UNDER A WHITE POLYETHYLENE TENT[1]

NORMAN E. PELLETT, DAPHNE DIPPRE, and ANN HAZELRIGG

Department of Plant and Soil Science
University of Vermont
Burlington, Vermont 05405

Abstract. A white polyethylene tent was used for 3 years to successfully root softwood cuttings of 16 shrubs and ground cover plants. Three treatments, intermittent mist with and without bottom heat, and watering 3 times daily with spray stakes without bottom heat, were successful procedures for rooting most kinds of plants. A heated rooting medium was detrimental for rooting some kinds of plants. The heated medium reached a higher temperature on sunny days than unheated medium. When the outdoor temperature reached 26°C (82.4°F), air temperatures in the tent were not detrimental to the cuttings.

REVIEW OF LITERATURE

We have identified a variety of landscape shrubs adapted for northern landscapes (5). To encourage northern nurserymen to propagate these without major investment in equipment, we investigated several methods for summer outdoor rooting of cuttings under a white polyethylene tent.

Paul Joly, Windsor Road Nursery, Cornish, N.H., has used a white polyethylene tent for rooting cuttings during the summer. We adapted his structure for our studies because we felt that a white polyethylene tent would result in acceptable maximum temperatures and prevent rapid drying of cuttings which occurs if an intermittent mist system fails in an open frame. Nurserymen have successfully rooted cuttings under light transmitting covers during summer (1,4). Some light reduction by covers did not inhibit rooting of cuttings (3).

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[1] Vermont Agr. Exp. Sta. Jour. Art. No. 532.

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The effect of three systems on rooting of softwood cuttings were compared in 1980 and 1981: (1) intermittent mist, bottom heat, (2) intermittent mist, no bottom heat, and (3) watering 3 times daily with Twin Rod Spray Stakes (Chapin Watermatics, Inc., Watertown, N.Y. 13610). Systems 1 and 2 were compared again in 1982 for their effect on rooting cuttings and on medium and air temperatures in the tent.

MATERIALS AND METHODS

Propagation beds 0.9 x 4.5 m (3 x 15 ft) were prepared at the University of Vermont, Burlington, Vermont by covering thin-wall conduit arches with a white polyethylene sheet (Visqueen 1505 white greenhouse film) (Fig. 1). The beds were prepared by driving 40 cm (18 in) lengths of 1.9 cm (¾ in) diameter conduit at 76 cm (30 in) intervals and fastening them to a 3.5 x 13 cm (2 x 6 in) wooden frame 4.5 m (15 ft) in length and 0.9 m (3 ft) in width. Sections of 3 m (10 ft) long by 1.3 cm (½ in) diameter thin-walled conduit were arched over the bed and anchored in the larger diameter supports attached to the frame.

White polyethylene (4 mil) was stretched over the arches and fastened on one side. The opposite side was covered by gravel for easy access. The south end of the mist bed was enclosed by the polyethylene while the north end was left uncovered.

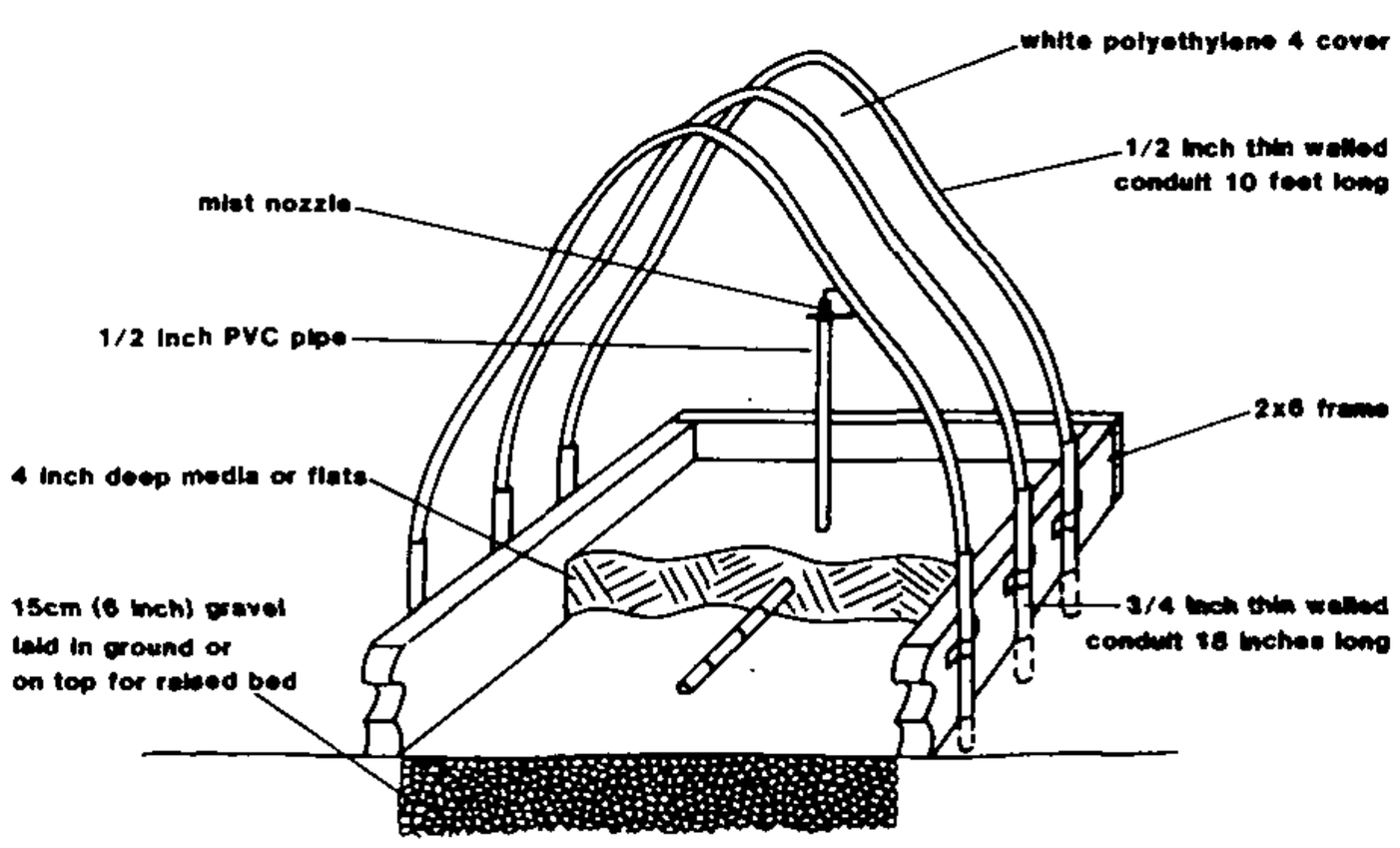

Figure 1. Components of white polyethylene propagating tent.

The frames were set on a 15 cm (6 in) deep base of gravel covered with wire mesh to prevent erosion of rooting medium. Lead heating cables for heating were placed on the mesh with not more than 10 cm (4 in.) between cables. Temperature controls for medium heating were set at 22°C (72°F) maximum. A 10 cm (4 in.) deep 1:1, v/v, mixture of perlite and vermiculite was used as the rooting medium.

An intermittent mist system consisted of Flora Mist nozzles (E. C. Geiger, Harleysville, PA 19438) on 1.3 cm (½ in) vertical PVC pipe 46 cm (18 in.) risers spread 16 cm (2 ft) apart. The mist was regulated by a Mist-A-Matic (E. C. Geiger) near the center of the structure. Water was applied at 40 to 60 psi.

Spray Stakes were attached to a 1.9 cm (¾ in) polyethylene pipe extending along one edge of the frame. Twin Rod Spray Stakes 61 cm (24 in) high were spaced every 76 cm (30 in) in the bed. This system was controlled by a timer which turned the water on for 10 min, 3 times daily at 0800, 1200, and 1700 hr. Heating cables were not used in this treatment.

Sixteen kinds (taxa) of ornamental plants were tested for rooting of cuttings. A group of 12 taxa each year was considered a block and was replicated 5 times in each treatment. Within a block there were 10 cuttings of each taxon, taxa being randomized within each block.

All cuttings taken during the first 2 weeks in June were dipped in a commercial rooting hormone (IBA, 0.1, 0.3 or 0.8% in talc) suited to the species before placing in the bed. Cuttings were considered rooted when at least 1 root, 1 cm long was observed at weekly evaluations.

Temperatures were recorded at 3 hr intervals during August, 1982 at 6 locations throughout the propagating beds. At each position 2 temperatures were recorded, one 7.5 cm (3 in) above the medium and the other embedded in the medium 2.5 cm (1 in) above the heating cable. Temperatures in the tent for typical days were compared with Vermont outdoor temperatures (Fig. 2).

RESULTS

All treatments resulted in 50% or better rooting of most taxa for most years, a percentage we find acceptable for economic nursery production with the systems used. No one treatment consistently promoted better rooting of all taxa over several years. For most species, bottom heat did not consistently increase rooting (Table 1). Bottom heat resulted in a lower rooting percentage for *Viburnum sargentii* 'Onondaga' in 1982 and *Spiraea* × *arguta* 'Compacta' in 1981.

Watering 3 times daily with Spray Stakes gave acceptable rooting of most kinds of cuttings. The surface of cuttings dried between waterings and they became more mature (stems more rigid) under this regime. The more mature cuttings rooted better under Spray Stakes than less mature cuttings. *Juniperus sabina* 'Blue Danube' and *Lonicera* × *bella* cuttings rooted best with Spray Stakes in 1981 when cuttings were more mature

(Table 1). *Berberis, Hydrangea, Cornus,* and *Viburnum* cuttings under Spray Stakes rooted as well as, or better than those under intermittent mist.

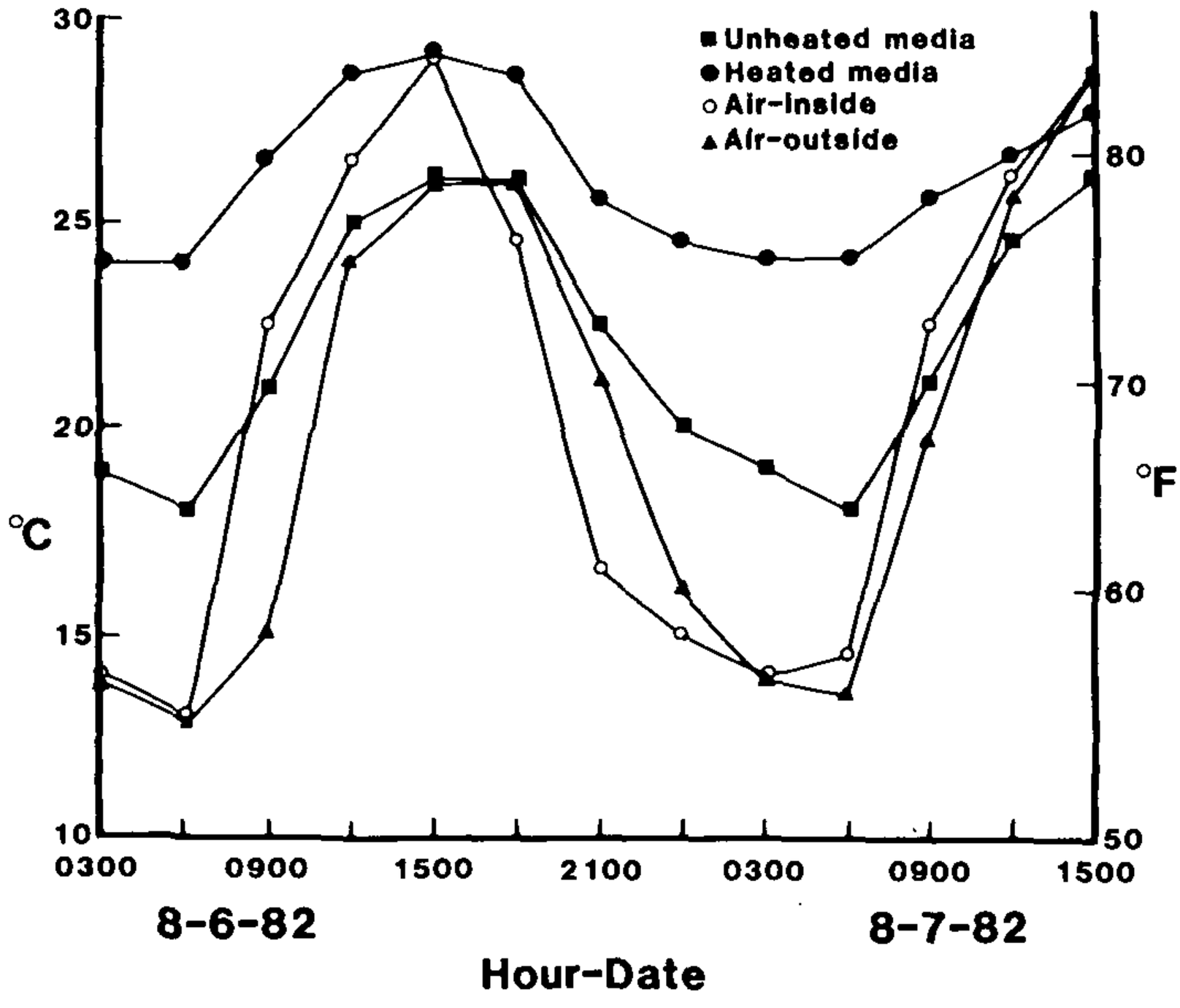

Figure 2. Comparison of rooting media and air temperatures.

Table 1. Effect of mist, with and without bottom heat, and Spray Stakes watering on percent of cuttings rooted under a white polyethylene tent.

Taxon (weeks for rooting)	Mist (no bottom heat)	Mist, (bottom heat)	Spray Stakes
Berberis thunbergii (7)			
1980	100a[1]	94a	100a
1981	62a	64a	96a
1982	96a	86a	—[2]
Cornus sericea 'Isanti' (3)			
1981	92a	60a	75a
1982	94a	63a	—
Euonymus europaea 'Burtonii' (9)			
1982	84a	87a	—
Forsythia mandschurica 'Vermont Sun' (8)			
1982	78a	82a	—
Hydrangea paniculata 'Grandiflora Compacta' (2)			
1980	100a	98a	100a
1981	100a	100a	92a
Iberis 'Alexander's White' (3)			
1980	36a	56a	62a

Table 1. Effect of mist, with and without bottom heat, and Spray Stakes watering on percent of cuttings rooted under a white polyethylene tent (continued).

Taxon (weeks for rooting)	Mist (no bottom heat)	Mist, (bottom heat)	Spray Stakes
Juniperus chinensis 'Hetzii' (9)			
1981	38b	18b	94a
1982	71a	67a	—
Juniperus sabina 'Blue Danube' (8)			
1980	56a	74a	46a
1981	22b	10b	64a
1982	82a	74a	—
Ligustrum vulgare 'Cheyenne' (6)			
1980	38a	66a	13a
1981	86a	72a	92a
1982	90a	66a	—
Lonicera × *bella* (6)			
1980	64a	56a	60a
1981	40b	18b	86a
Pachysandra terminalis (8)			
1982	96a	94a	—
Phlox subulata 'White Delight' (5)			
1981	92a	82a	90a
Prunus × *cistena* (6)			
1980	20a	46a	14a
1981			15
1982	77a	81a	—
Spiraea × *arguta* 'Compacta' (3)			
1980	88a	90a	84a
1981	86a	54b	44b
1982	90a	90a	-
Viburnum lantana 'Mohican' (7)			
1982	90a	78a	—
Viburnum sargentii 'Onondaga' (6)			
1980	100a	100a	75a
1981	80a	77a	90a
1982	98a	59b	—

[1] Means in a row followed by the same letter are not significantly different at the .05 level, Duncan's Multiple Range Test.
[2] A dash indicates no cuttings in that treatment or no date collected.

Variable results from year-to-year appeared to have been affected by vigor of cuttings. Shorter shoot growth of stock plants due to low rainfall prior to cutting appeared to affect rooting response. For example, *Prunus* × *cistena* cuttings gave poorer rooting in 1980 and 1981 than in 1982 when cuttings were more vigorous.

Air temperatures in the tent were comparable to outdoor air temperatures during the night, but during typical sunny

days rose 3° to 5°C higher (Fig. 2) When the outdoor temperature reached 26°C (70°F) on a typical sunny day, the air temperature at foliage level in the tent was 29°C (82°F). Temperatures were warmest at the closed south end of the tunnel and coolest near the open end.

Media temperatures changed rapidly in response to air temperatures (Fig. 2). A typical daily event is shown for August 6, 1982 when between 0600 and 1500 hr, the unheated media temperatures rose from 14°C (57°F) to 29°C (84°F). A minimum temperature between 22° and 24°C (72 to 76°F) was maintained in the heated medium but rose rapidly during sunny periods to temperatures 5 to 6°C above the unheated media. The temperatures of the heated medium were often above 30°C which may be detrimental to rooting of cuttings.

The temperature of the unheated media generally was 1.5° to 3°C warmer at the closed end of the tent than at the open end (Fig. 3). This did not result in detectable differences between rooting of cuttings at either end.

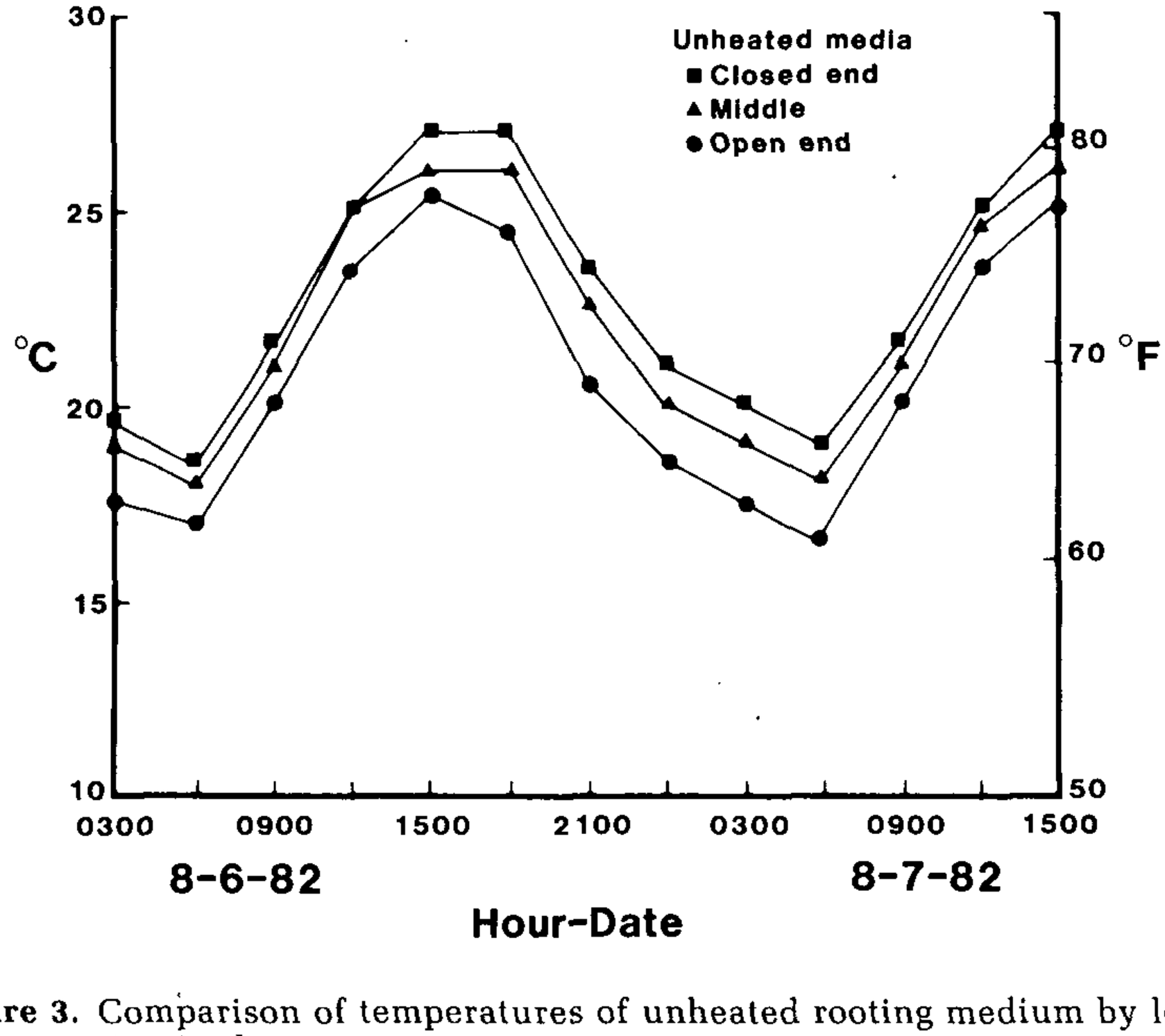

Figure 3. Comparison of temperatures of unheated rooting medium by location in the tent.

DISCUSSION

Summer maximum temperatures in our climate under the white polyethylene apparently were not detrimental to rooting. Burlington, Vermont, temperatures average 26.4°C (79.5°F)

maximum and 16.6°C (59.8°F) minimum during July, the warmest month, with a daily average of 20.9°C (69.7°F) (2).

The white polyethylene tent provided a suitable environment for summer rooting of cuttings using either frequent misting or watering 3 times daily. The polyethylene tent system is useful for small nurseries where supervising personnel often are not present to guard against failure of an intermittent mist system. The polyethylene cover may reduce the loss of cuttings from system failure. The success of 3 daily waterings from Spray Stakes may result in less leaching of minerals from cuttings than frequent misting, although we did not measure mineral content of cuttings.

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CARMINE RAGONESE: It's hard to believe that you can get good rooting under the white plastic.

NORMAN PELLETT: We have no problem.

HARRISON FLINT: Just a comment on the Mist-A-Matic system. It does not work well in calcareous soils.

CHARLIE PARKERSON: Did you see any differences because of the drying.

NORMAN PELLETT: The spray stake bed got a little warmer, maybe 2°C.

CLAYTON FULLER: Why did you not use clear poly with a little shading to increase the air temperature, which we have found to increase rooting.

NORMAN PELLETT: We just essentially used the same system as Paul Joly, who had good rooting.

GERALD VERKADE: Why was the medium temperature so difficult to control?

NORMAN PELLETT: I am not sure what your experience with thermostats has been, but they appear to be very difficult to control.

HARRISON FLINT: Just a comment on controlling medium temperature with a thermostat. For relatively good control the trick is to keep the sensing unit close to the cable. If you keep the sensing unit too far from the cable, the medium will overheat close to the cable.

DAVE BAKKER: I think we nursery people are often cheap when we buy thermostats. You can buy thermostats with a 1 to 2 degree differential, if you order special.

A COMPARISON OF DIFFERENT HEAT SOURCES IN OUTDOOR MIST BEDS[1]

JOHN J. MCGUIRE, CHARLES G. MCKIEL AND STEPHEN MACDONALD

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Abstract. A comparison was made of five different unheated or heated insulated outdoor mist systems and a heated greenhouse mist system. Systems were evaluated for seasonal operating and construction costs as well as rooting efficiency of broadleaved and narrowleaved evergreens and deciduous plants. Spring propagation is practical in southern New England and three successive crops could be obtained in a heated outdoor system.

REVIEW OF LITERATURE

Increased cost of fossil fuels has placed plant producers in the U.S. northeast at an economic disadvantage. It has also stimulated research in designing both energy efficient plant production procedures and structures (1,2,3,4,5,6,7,8,10).

Recent studies have shown that it is not practical to attempt to provide all of the heat necessary for propagation from solar energy on an annual basis because of the limited efficiency of present solar energy systems in the north (11). However, it has been shown that such systems can be used to supplement conventional fossil fuel systems with fuel cost

[1] Approved by the Director of the Rhode Island Agricultural Experiment Station, Contribution No. 2170. Research was supported in part by funds from the Hatch Act.

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savings of up to 40 to 50% (11). Such savings over a number of years should offset initial capital outlay for a solar energy system (11).

One of the most efficient designs of a propagation or production bed is to supply heat directly to an insulated bed as bottom heat, since this is where root activity takes place (3,7).

MATERIALS AND METHODS

This research was done to determine the feasibility of propagating commercially important crops in outdoor beds which were insulated and heated only in the rooting medium and only during the seasons of higher solar radiation.

This approach appeared to be practical since the technology is available to make use of solar energy as well as improved insulation which reduces the required ratios of collector panels to area of bed space.

The idea of propagating coniferous crops in outdoor mist beds is not new. It has been done for many years in southern New England (9) but little, if any, spring or summer propagation was done with broadleaved evergreens, particularly rhododendron, because of the time required to attain a good root system. Also, if existing beds were insulated, fuel savings could be realized as well as reduced time of production for each crop. This could result in at least three crops per season with no building required and no energy expended on fans for cooling. It was also the objective of the work to compare construction costs for different bed designs as well as monthly operating costs for energy expended. Previous work at this experiment station had shown outdoor propagation was possible, but without the addition of heat in cool summers, crops required considerable more time than was available in summer.

Five outdoor mist beds were constructed in 1982-83 at the Rhode Island Agricultural Experiment Station. Concrete blocks laid without mortar joints were used for the sidewalls. The walls and bottom of the beds were insulated with 2.5 cm rigid foam polyisocyanurate (R = 7.2 at 20°C). The bottom insulation was sloped toward the middle with a 7.5 cm gap provided down the center for water drainage. In addition, one bed was constructed without insulation.

All outdoor beds had separate propagating areas of coarse sand and of a 50:50 mixture of sphagnum peatmoss and medium grade vermiculite. Coarse sand was used in each case to bring the medium level to approximately 20 cm above the bottom heat.

During the 1983 spring (April 1 to June 16) propagation period, all beds were covered with a 0.6 cm layer of micro-foam through which the cuttings were placed.

In two beds, hot water was circulated through 2 cm (O.D.) polyethylene pipe placed 15 cm apart in the bottom of each bed. Feed and return pipes alternated to facilitate uniform heat distribution. A small, thermostatically controlled pump (Taco No. 007) provided water circulation in each bed. One of the beds was supplied with heat from a 50 gal electric hot water heater using one 4500 watt heating element and 40°C thermostat setting. The other bed obtained supplemental heat from a 300 gal storage tank heated by six Revere solar panels (Model No. 42121) mounted on a 23 degree (5 in 12 slope) south-oriented shed roof. A drain back system, controlled by a differential thermostat (Independent Energy No. C-30), was used for solar energy collection. The six, 0.91 × 2.44 m, panels had a combined total solar energy collection area of 13.4m^2 providing a collector-to-bed area ratio of approximately 7.

Low voltage resistance wire heating was used in the third bed. Two 500 watt transformers (120 volt primary, 16 volt secondary), with thermostat control, were used to feed No. 10 gauge galvanized wire having 17.5 cm bed spacing. The length of resistance wire powered by each transformer was about 29 m, providing a capacity of approximately 97 W/m^2.

A fourth bed received supplemental heat from a south-oriented solar heated air panel having a 25 degree slope. Heat storage for the propagation bed was provided by a layer of 5 to 6 cm stone approximately 53 cm deep covered with 8 cm of pea stone. This was located beneath the 20 cm propagation medium. The rock storage had 5 x 40 cm air supply ducts along each side and a 10 x 40 cm return air duct down the center. These ducts were connected to the solar air panel. Air circulation was provided by a small fan (Dayton No. 4C666) controlled by a differential thermostat. The on-site built solar panel consisted essentially of a corrugated fiberglass cover, 5 cm air space, over matte black-painted collector plate (aluminum flashing), 1.9 cm air flow space, 0.6 cm plywood, 2.5 cm polyisocyanurate insulation and 0.9 cm plywood bottom. The 1.22 x 4.88 m panel provided a 0.6 ratio of collector to bed area.

The fifth outdoor bed was unheated and served as a control.

A raised bed of conventional design located in a quonset-type polyethylene-covered greenhouse was also utilized in this study. No bottom heat was provided but a minimum temperature of 20°C was maintained by a forced hot air furnace.

Thermostats were set to maintain bed temperatures of 20°C in 1982 and in the spring of 1983. Bed temperatures were recorded at 6 hr intervals (6 a.m., 12 noon, 6 p.m. and 12 midnight) by a 24 point strip chart recorder.

Electrical energy used for supplemental heat in the electric hot water and resistance cable beds was metered and recorded. Electrical energy consumption during 1983 was also monitored for the pumps used with the solar hot water panels and bed.

Selected cultivars of broadleaved and narrowleaved evergreens, and deciduous plants were propagated during the summers of 1982 and 1983 and in the spring of 1983. Broadleaved evergreen plants were propagated in a medium of equal parts of sphagnum peat moss and medium grade vermiculite; the others were propagated in coarse sand. Twenty-five cuttings of each cultivar were placed in each bed of each of the six systems.

A minimum grade was set for all cuttings. Broadleaved evergreens were not considered rooted unless there was a rootball of at least 2 cm; the number of roots per cutting were not counted unless they were at least 25 mm long. When cuttings in any bed had roots of sufficient length, cuttings of that cultivar in all beds were harvested (Table 1).

RESULTS

Temperature of Media. If the propagating medium had no mulch, the heated beds outdoors had the capacity to maintain a temperature differential between outside air and the medium of approximately 10 to 15°C. If mulched with microfoam they could maintain a difference of 15 to 20°C (Table 2). The greatest fluctuation in minimum average temperatures occurred in the solar-heated beds. Minimum night temperatures in Rhode Island in the summer of 1983 averaged 20°C which means little heat was needed to maintain a temperature of 25°C. Costs were significantly higher when heated beds were used in April or May but dropped rapidly thereafter.

Differences in the temperatures maintained in the beds by the various supplemental heating systems were not great except for periods of rainy weather. During these times, especially with rainfalls of 10 to 13 cm in 24 hr as occurred in the spring and early summer of 1983, the heat required to maintain desired bed temperatures exceeded the capacity of the systems. In addition, temperature reductions were greater and occurred for longer periods in the solar heated beds as solar energy collection was minimal in this rainy and cloudy weather.

Table 1. Average rootball diameter[1] (cm) and rooting percentage of five *Rhododendron* cultivars in outdoor and indoor progagating beds — 1982.

Propagation duration (weeks)	Cultivar	Unheated		Electric hot water		Solar hot water		Indoor greenhouse bed	
		Average diam. (cm)	Percent rooted[2]	Average diam. (cm)	Percent rooted	Average diam. (cm)	Percent rooted	Average diam. (cm)	Percent rooted
9½	'Boule de Neige'	4.7	22	5.8	53	5.2	38	8.1	67
13½	'Nova Zembla'	5.0	70	6.6	96	7.3	91	7.4	70
15	'English Roseum'	5.1	91	7.4	98	7.5	99	8.7	97
9	'Mrs. P. Den Ouden'	5.2	74	8.3	94	7.7	94	8.1	77
9½	*R.* × *chionoides*	5.2	40	5.6	86	6.9	80	6.7	51
	Average - all cultivars	5.0	59.4	6.7	84.5	6.9	80.4	7.8	72.4

[1] Twenty-five cuttings per treatment.
[2] Percent calculated on cuttings with a minimal root ball diameter of 2.0 cm

Table 2. Comparison of average night temperature of propagating medium of peatmoss and vermiculite in different heated and unheated outdoor mist systems — 1983.

Heating system with surface mulched (microfoam)	Spring (4/6-6/17)	Summer (6/20-9/30)
Low voltage galvanized wire	69 ± 7.4[1]	71 ± 6.0
Solar hot water	70 ± 10.5	77 ± 6.0
Electric hot water	71 ± 6.6	74 ± 5.0
Greenhouse hot air	72 ± 7.6	74 ± 9.0
Solar air	—	74 ± 9.0
Unheated	60 ± 11.0	70 ± 7.3
Air	52 ± 11.8	65 ± 10.0

[1] Mean ± standard error.

In the summer direct solar radiation on the insulated beds often resulted in temperatures exceeding the thermostat settings for a 24 hr period.

Cuttings of two *Taxus* cultivars rooted well in the outdoor heated system and in the heated greenhouse but did not root in the unheated outdoor bed (Table 3).

Table 3. Rooting results of two *Taxus* cultivars[1] in outdoor heated and unheated mist beds and heated greenhouse mist bed.

Taxus cultivar and propagation duration	Outdoor mist bed				Greenhouse mist bed	
	Electric hot water		Unheated		Hot air	
	% rooted	index*	% rooted	index	% rooted	index
T. × *media* 'Hicksii' 4/5-6/13	100	1.6	8	.08	100	1.8
T. cuspidata 'Densiformis' 4/7-6/13	92	1.1	0	0	96	2.1

[1] Twenty-five cuttings per treatment.
* Index = a measure of number of roots/cutting over 25.4 mm. 1 = 0-10, 2 = 11-20, 3 = 21-30, 4 = 31-40, 5 = over 40.

Rooted cuttings were equal to similar liners produced by local nurseries by November, 1983. Commercial cuttings were propagated in heated greenhouses in November, 1982 and maintained in the greenhouse until June, 1983 when they were planted in liner beds.

Heated outside beds produced larger *Rhododendron* root-ball diameters than the unheated bed in 1982 but higher summer temperatures in 1983 resulted in less difference between the outdoor beds in 1983. Results with deciduous plants also showed less difference in the summer when compared with spring propagated plants.

Rooting results varied slightly among outdoor heated bed types but in general were equal to those obtained in the greenhouse.

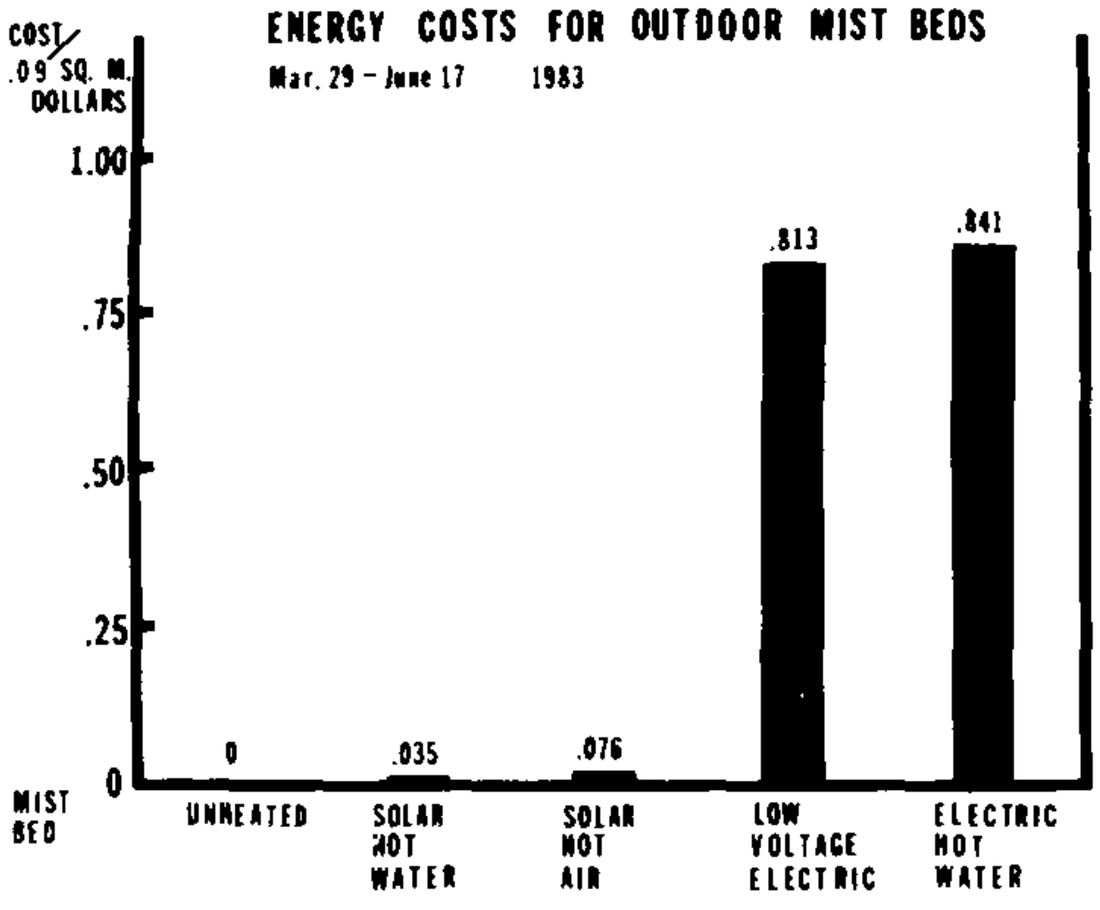
DISCUSSION

It is an accepted fact that systems involving either solar-heated water or air are more expensive to construct than the low voltage or electrically heated outdoor systems, since either a storage area for rock or water is required as well as a solar collector area. Construction costs for the beds in this study were calculated (Figure 2). Operating costs were also calculated and found to be almost in the reverse order of the construction costs (Figure 1). When one considers the construction cost of either a greenhouse ($4.50 to 6.00/sq ft) or plastic-covered greenhouse ($1.10 to 1.40/sq ft) (1) and added costs for heating ($1.75 to 1.00/sq ft) and/or ventilating ($.60-.80/sq ft) (1), it is apparent that the cost of all but the solar-heated system is less than a greenhouse system and similar to that of a plastic house since either structure would also have to include the additional cost of a propagation bed. However, both electrically-heated systems approach the costs of a greenhouse in operation, except in summer when no energy need be expended for cooling outdoor systems (Figures 1,2). However, when surface area mulch was removed in the summer and minimum temperatures were raised, energy costs increased for fossil fuel systems. Labor costs are not included in any of the comparisons.

It is possible to propagate *Taxus* cultivars and other narrowleaf evergreens outdoors or indoors in the spring within 2 months as opposed to indoor winter propagation which requires 6 months in heated structures, as is commonly done in New England. Production costs for these plants were not computed but since cuttings are more closely spaced than broadleaved evergreens and rooting occurs in 6 to 8 weeks instead of 8 to 10 weeks, costs would be low.

Selected cultivars of deciduous plants propagated in the spring in outdoor-heated beds and subsequently placed in 15 cm containers reached a standard grade of 60 to 72 mm by November 1, 1983. It is recommended that minimum temperatures in summer be maintained at 20°C to reduce operating costs.

It would appear that insulated, heated outdoor mist beds could be used to produce a variety of woody plants at competitive prices. It is up to the individual manager to determine which type of heat source is adaptable to the facility. (Tables 4 and 5).



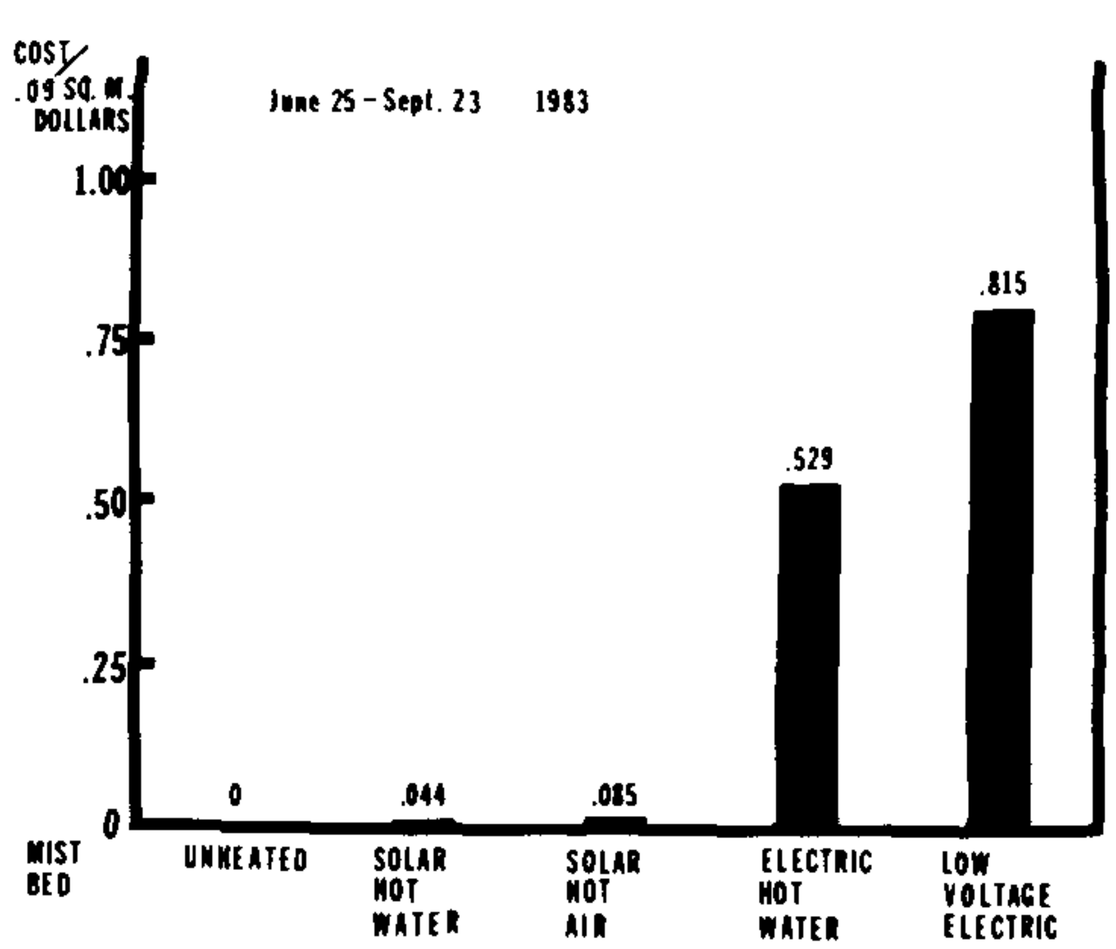


Figure 1. Energy costs for outdoor mist beds.
Above. Spring propagation period. March 29-June 17, 1983.
Below. Summer propagation period. June 25-September 23, 1983.

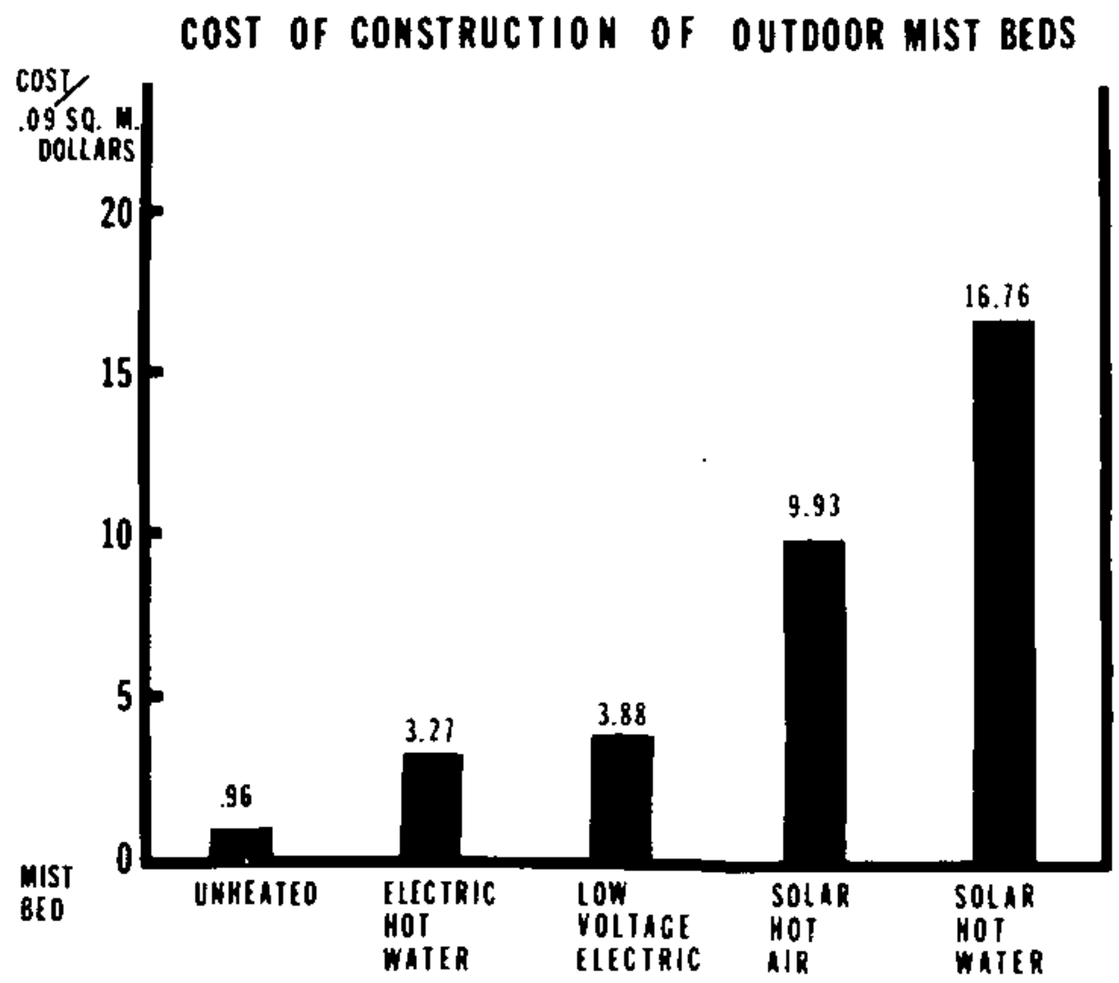


Figure 2. Cost of construction of outdoor mist beds (labor not included).

Table 4. Rooting results of selected broadleaved evergreens[1] in outdoor heated and unheated mist beds and greenhouse mist bed.

	Outdoor mist bed				Greenhouse mist bed	
	Electric hot water		Unheated		Hot air	
Plant and propagation duration	Percent rooted	diam. (cm)	Percent rooted	diam. (cm)	Percent rooted	diam. (cm)
Rhododendron 'Nova Zembla' 4/7-8/2 Growth regulator — Hormex 45	48	5.4	48	3.8	24	3.7
Kalmia latifolia 'Pink Surprise' 4/6-8/4 Growth regulator — IBA 2000 ppm aqueous dip 5 sec.	60	7.8	63	6.3	30	7.2

[1] Twenty-five cuttings per treatment.

Table 5. Rooting efficiency of selected deciduous shrubs[1] in heated and unheated mist beds — 1983.

Cultivar and Propagation Duration	Solar air		Solar water		Electric low voltage		Hot water		Unheated outdoor		Greenhouse	
	Percent rooted	index*	Percent rooted	index	Percent rooted	index	Percent rooted	index*	Percent rooted	index	Percent rooted	index*
Hibiscus syriacus 'Lady Stanley' 7/25-8/9	100	1.0	100	1.0	100	1.0	100	1.0	100	1.0	100	2.1
Viburnum carlesii	92	1.9	76	1.0	96	1.9	84	1.2	96	1.7	100	1.9
Viburnum sieboldii	96	2.5	96	2.0	100	3.0	96	1.9	80	1.3	96	2.4
Viburnum plicatum forma *tomentosum* 'Pink Beauty' 7/23-8/23	88	1.4	92	1.5	92	1.8	88	1.4	76	1.0	80	1.4
Magnolia stellata 7/11-9/8	84	1.8	76	1.4	52	1.0	60	2.0	40	0.8	36	.0
Euonymus alata 7/13-8/23	88	1.4	92	1.5	92	1.8	88	1.4	76	1.0	80	1.2

* Index = a measure of the number of roots/cutting over 25.4 mm. 1 = 0-10, 2 = 11-20, 3 = 21-30, 4 = 31-40, 5 = over 40.
[1] Twenty-five cuttings per treatment.

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CHARLIE PARKERSON. Did you put microfoam over the beds to keep the heat in? If so, how did you harvest the cuttings?

JOHN MCGUIRE: Yes, we did in the spring and just pulled the cuttings through. We did not use microfoam in the summer.

PETER VERMEULEN: Were the *Callicarpa* made from hardwood cuttings?

JOHN MCGUIRE: Yes, they were.

MIKE KOCZOROWSKI: Do you expect any moisture accumulation in your isothiocyanate beds?

JOHN MCGUIRE: The bed is quite deep with 9 in of medium and the rooting zone is quite far up from the base.

MIKE KOCZOROWSKI: Do you know if moisture will cause any accelerated deterioration of the insulating material? We have found that moisture will deteriorate Thermex.

JOHN MCGUIRE: We are not sure because this is only the second year. I would recommend that the side insulation be put on the outside.

GERALD VERKADE: Just a comment. This system looks like it might be useful for December rooting of Japanese maples.

VENTILATED HIGH HUMIDITY PROPAGATION

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Abstract. The concept of ventilated high humidity propagation is described as well as the equipment necessary for its operation. Vegetative cuttings were rooted with this sytem of propagation by providing them with a mechanically humidifed atmosphere. Solar heating, the primary problem of high humidity propagation, was controlled by shading and ventilation. This system also minimized the problems of more conventional types of propagation.

Ventilated high humidity propagation is a concept of propagation developed by the author to improve cutting propagation. Saturation and evaporative cooling of the propagation medium are problems of mist propagation with solutions involving almost every conceivable types of heating and combination of propagation medium applied to some form of misting. The obvious solution to these problems is to apply less water as smaller droplets but this solution creates a greater problem of nozzle plugging. The reduction of evaporative cooling through the use of enclosures further increased saturation and introduced the problem of heat entrapment. Thus the problems of mist propagation did not lead to any changes that evolved into anything other than mist systems until this research was undertaken.

Even though minimized, the problems of mist persist. The popularity of mist as a means of propagation despite its problems is due to its adaptability to automation. Automated systems have the distinct advantage of yielding reproducible results with a minimum of labor. Further improvement of propagation required considerable divergence from the commonly accepted concepts of mist as well as improvement over approximately 40 years of mist research. Such divergence was also discouraged by the difficulty in finding satisfactory equipment for testing new ideas.

Research on the concept of ventilated high humidity propagation was begun in 1974 as a novel means of reducing the amount of water applied and for controlling the solar heat accumulating in enclosures. The resultant rooting of cuttings was very promising but existing equipment was expensive, inadequate, and unreliable. After six years, the first commercially feasible humidifier for ventilated high humidity propagation was built. Now equipment is available from several manufacturers as automated and reasonably reliable systems for commercial propagation. Because of its recent introduction,

ventilated high humidity propagation is understood by relatively few propagators. My intent is to explain this concept in practical terms and describe existing equipment for making this concept a feasible propagation system.

Ventilated high humidity propagation is a fairly descriptive title for this concept of propagation. Ambient air is continuously humidified during the daylight hours to replace the air around the cuttings as it is heated by solar radiation.

Outside air, which is below 100% relative humidity, is humidified by mixing an excess of small water deposits with it as it enters the greenhouse. The smaller the droplets, the more energy required to make them. Hence, the tendency is to use larger droplets and carry them on a fairly high velocity wind current until they evaporate to satisfactory smallness. The wind current, by being directed over the cuttings, aids in the removal of solar heated air from among cuttings. The excess of droplets is necessary to restore high humidity as the air is being heated. High quality fog requires much slower wind velocities because of the much greater surface area of the larger number of small droplets exposed to air.

Solar heat is the primary problem of summer propagation. Sunlight impinges upon the cuttings and propagation medium and is converted to heat. This heat creates a hot microclimate among the cuttings that lowers the humidity and wilts the cuttings. This heat has to be continuously removed or must be prevented from forming by shading. In practice, both methods are used. At least 200 foot candles of light are necessary for the cuttings. Therefore shading is used to eliminate unnecessary heating and ventilation removes any excess heat. Air movement replaces the need for shading and is most necessary where droplet sizes are large and shading is minimal.

Exhaust ventilation completes the concept and must be adequate for removal of heated air. Generally exhaust vents are located either at the opposite end from the ambient air intake or in a higher position. The exhaust fans or vent openings may be thermostatically controlled to maintain a temperature near the optimum for root initiation.

Temperatures in excess of 90°F are considered inhibitory to root initiation and in excess of 100°F as destructive of new roots that have already grown. Hence, the temperature can be beneficially maintained near 90°F during root initiation when high temperature favors root initiation. Lowering the temperature by increasing the ventilation after root initiation favors root growth and conditions the plant for growth on its own.

Successful propagators have used this concept by installing humidification equipment at the intake vents and at intervals throughout the length of a greenhouse. Hot air was vented at the opposite end by a 3000 to 4000 cu ft/min thermostatically controlled exhaust fan. Fifty to 70% shading was used on greenhouses during the summer and all other vents were closed. Ground beds or flats at ground level have been more successful than raised benches, particularly mesh covered benches. Heat rising from under and between benches lowered the humidity at the bench level resulting in wilted cuttings. The success of fall and winter propagation depended upon the amount of solar radiation. The best results were obtained with little or no shading during cool sunny weather. Humidification was reduced to very low levels to prevent excessive dripping from the greenhouse ceiling when the weather was too cool to operate the fan. While rooting was slower than during the summer, no supplemental heating was required during non-freezing weather.

The high pressure fog developed by the Mee Industries equipment (see page 100) is excellent for this type of propagation. By concentrating the nozzles at the air intake, a blanket of fog is formed which drifts over the cuttings as it traverses the length of the greenhouse. Nozzles at intervals throughout the greenhouse replenish the fog and maintains high humidity. Because the water is dispersed as a true fog, only slow movement of the fog is necessary to remove heat from among the cuttings if the greenhouse is shaded.

The early models of the Agritech humidifier produced larger droplets that were difficult to maintain airborne. Turbulence in the airflow caused a coalescence of the droplets and saturation near the humidifier. Improved fan blades and a pressurized hub in the humidifier have greatly improved the quality of fog. An oscillator on the humidifier continuously changes the direction of outflow to cover approximately 1000 sq ft per humidifier. Cuttings must be within approximately 35 ft of the humidifier for satisfactory removal of heated microclimates among the cuttings. The best results have been observed in the typical 30 x 100 ft quonset type greenhouse when 3 units were located 33 ft apart, two on one side alternated with one on the other side to completely cover the cuttings with 90 degree quadrant oscillations directed toward the exhaust fan. These units are easily installed and provide an economical means of converting greenhouses for propagation.

A new unit has been used for experimental propagation. The quality of fog is good and the equipment is light and simple to operate. It has no nozzles to plug and is mounted on

only one motor. It would be used similarly to Agritech humidifiers and should be available by spring.

As with anything new, acceptance is not always easy, yet some propagators are already convinced that ventilated high humidity propagation is a concept which will remain as a choice for propagators. They are finding that cuttings root better and remain stronger than those from their previous systems. As equipment improves, more propagators should find this to be true.

DALE MARONEK: Don, are you supporting the concept that you should not use any hormones in this system?

DAN MILBOCKER: This has been our experience. The absorbed heat into the medium appears to take the place of the hormone. In most cases you can eliminate the hormone completely.

DALE MARONEK: That seems to go along with what we have found in our nursery where bottoın heat plus a hormone causes basal burning. But if we do one or the other we do not get burn.

DAN MILBOCKER: We have seen that high temperature (above 90°F) favors root initiation but lower temperatures are better for root growth.

PETER VERMEULEN: Do you need to use a fungicide and what about water quality?

DAN MILBOCKER: No, we did not use fungicides on the experiment I showed you. Water quality was important on the old units but the newer units do not have a true nozzle and water quality is not important.

PROPAGATION: FOG NOT MIST

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(See Western Region, page 100)

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Tuesday Afternoon, December 6, 1983

The afternoon session was convened at 2:00 p.m. with Dale Maronek serving as moderator.

Editor's Note: Dale Maronek moderated a group of short presentations on stripping of cuttings. The following paper by Dale Maronek, Ron St. Jean, Tom McCloud, Vernon Black and Dan Studebaker were part of that session.

STRIPPING VS. NONSTRIPPING ON ROOTING OF WOODY ORNAMENTAL CUTTINGS — GROWER RESULTS

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17268

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Abstract. The effect of two different wounding treatments on rooting of cuttings was determined for 19 species. Rooting of stripped (wounded) or nonstripped cuttings varied by species. Differences on root morphology were found among stripped and nonstripped cuttings of some species. The nonstripping treatment saved considerable time during the cutting preparation process. However, the probable money saved during cutting preparation was offset by increased time for collection of suitable wood, sticking of cuttings, and/or the area of space needed to propagate the nonstripped cuttings.

INTRODUCTION

Through the years, members of our Society have periodically presented information pertaining to the importance of wounding cutings in order to increase rooting and/or quality of the root system (2,3,4,5). Often, the discussion centered around the magnitude of the wound (2,3,4) rather than whether wounding is necessary at all. Since wounding is labor intensive, there is a need to determine the magnitude of wounding necessary to obtain acceptable rooting (2).

In recent years simply stripping the basal leaves off the cutting has been reported as an effective method of wounding (1). In speaking with individual propagators, many of them have experimented with rooting cuttings without wounding. Unfortunately, the results of many of these studies have not been published. Last year, Ralph Shugert of Zelenka Nursery, reported that unstripped *Taxus* cuttings exhibited comparable

rooting to stripped cuttings. He also pointed out the potential for savings in labor costs through the elimination of the stripping process.

Upon the suggestion of Leonard Stoltz, this year's program chairman, plans were made to expand upon Ralph Shugert's initial results and determine if some other plant species could be successfully propagated without wounding. Each of the authors of this paper were asked to propagate several different species with basal foliage stripped off the cuttings and a similar amount left intact or nonstripped. Everyone was to use their own commercial propagation practices with stripping and nonstripping being the only variables. Rather than individually discussing each of the author's materials and methods, the species used, along with other propagation information, is summarized in Table 1.

RESULTS AND DISCUSSION

The comparison of rooting percentages and the average of primary and secondary roots for cuttings of each stripped and unstripped species are summarized in Table 1. A discussion of each author's specific procedures and results follows below. In some instances, the roots on cuttings of a particular species were so profuse that no root counts were made.

Tom McCloud, Appalachian Nurseries. Shaded, summer softwood cuttings of *Euonymus alata* 'Compacta', *Lonicera pileata*, and late summer, semi-hardwood *Forsythia viridissima* 'Bronxensis' cuttings were stuck in raised greenhouse benches. At the time of lifting, root development on all species was sufficient for potting. The rooting percentages of stripped and nonstripped *Forsythia* and *Lonicera* cuttings were similar (Table 1.) However, the rooting percentage of nonstripped *Euonymus* cuttings was about 10 percent better than stripped cuttings.

In general, the root systems of *Euonymus*, *Forsythia*, and *Lonicera* nonstripped cuttings were better than stripped cuttings of the same species. Nonstripped *Lonicera* cuttings had more primary roots than stripped cuttings (Table 1). Roots on nonstripped *Forsythia* and *Euonymus* cuttings were 10 to 20% longer than those on stripped cuttings, suggesting that the nonstripped cuttings may have rooted earlier than stripped cuttings. These results concurred with results from a previous study in which nonstripped *E. fortunei* 'Colorata' cuttings rooted faster and had a better developed root system than stripped cuttings (McCloud, unpublished data).

Table 1. Cultural information and the effect of stripping or nonstripping on rooting of woody ornamental cuttings. Data listed by nursery and species.

Species	Cutting treatment	No. stuck	Date stuck	Date evaluated	Hormone treatment	Media	Duration of bottom heat and temperature Days C	Mist	Percent rooting	Ave. no. primary roots *	Ave. no. secondary roots *
					APPALACHIAN NURSERIES						
Euonymus alata 'Compacta'	Stripped	1,000	6-10-83	7-18-83	Wood's 1-20	60% perlite &	None	Int.**	86	NC***	NC
	Nonstripped	1,000	6-10-83	7-18-83	ibid.	40% vermiculite	ibid.	95	NC	NC	
Lonicera pileata	Stripped	100	7-20-83	9-1-83	ibid.	60% perlite &	ibid.	ibid.	90	8	NC
	Nonstripped	100	7-20-83	9-1-83	ibid.	40% vermiculite	ibid.	ibid.	90	12	NC
Juniperus horizontalis 'Wiltoni'	Stripped	1,000	8-24-83	11-7-83	ibid.	50% perlite &	ibid.	ibid.	70	6.1	2.6
	Nonstripped	1,000	8-24-83	11-7-83	ibid.	50% peat	ibid.	ibid.	24	5	3
Forsythia viridissima 'Bronxensis'	Stripped	100	9-2-83	9-23-83	ibid.	ibid.	ibid.	ibid.	100	14	NC
	Nonstripped	100	9-2-83	9-23-83	ibid.	ibid.	ibid.	ibid.	100	15.3	NC

Table 1. Cultural information and the effect of stripping or nonstripping on rooting of woody ornamental cuttings. Data listed by nursery and species (continued).

Species	Cutting *treatment*	No. *stuck*	Date stuck	Date evaluated	Hormone treatment	Media	Duration of bottom heat and temperature Days	C	Mist	Percent rooting	Ave. no. primary roots *	Ave. no. secondary roots *
					BAILEY NURSERIES, INC.							
Prunus virginiana 'Canada Red Select'	Stripped	78,000	6-13-83	10-10-83	750 ppm IBA	Sand	None		Int.	58	11	NC
	Nonstripped	100	6-13-83	ibid.	ibid.	ibid.	ibid.		Int.	60	10	NC
Lonicera xylosteum 'Compacta'	Stripped	47,500	7-6-83	ibid.	ibid.	ibid.	ibid.		ibid.	98	61	NC
	Nonstripped	100	7-6-83	ibid.	ibid.	ibid.	ibid.		ibid.	96	55	NC
Spiraea × *bumalda* 'Goldflame'	Stripped	100	6-16-83	10-10-83	None	Sand	None		Int.	94	13	NC
	Nonstripped	80,000	6-16-83	ibid.	ibid.	ibid.	ibid.		ibid.	90	17	NC
Syringa patula	Stripped	100	7-27-83	ibid.	750 ppm IBA	ibid.	ibid.		ibid.	97	51	NC
	Nonstripped	12,000	7-27-83	ibid.	ibid.	ibid.	ibid.		ibid.	96	36	NC
Prunus maackii	Stripped	44,000	7-27-83	ibid.	ibid.	ibid.	ibid.		ibid.	84	25	NC
	Nonstripped	100	7-27-83	ibid.	ibid.	ibid.	ibid.		ibid.	87	15	NC

Table 1. Cultural information and the effect of stripping or nonstripping on rooting of woody ornamental cuttings. Data listed by nursery and species (continued).

Species	Cutting treatment	No. stuck	Date stuck	Date evaluated	Hormone treatment	Media	Duration of bottom heat and temperature Days	C	Mist	Percent rooting	Ave. no. primary roots *	Ave. no. secondary roots *
					STUDEBAKER NURSERIES, INC.							
Juniperus chinensis 'Seagreen'	Stripped	1,045	1-20-83	5-23-83	Wood's 1-3	sand	98	18°	None	74.7	7.40	10.50
	Nonstripped	1,000	1-20-83	5-23-83	ibid.	ibid.	98	18°		39.6	6.16	7.30
Spiraea nipponica 'Snowmound'	Stripped	495	7-12-83	7-12-83	Wood's 1-10	ibid.	None		6 s./ 10 min.	72.1	NC	NC
	Nonstripped	495	7-12-83	ibid.	ibid.	ibid.	ibid.		ibid.	76.6	NC	NC
Forsythia × *intermedia* 'Lynwood'	Stripped	504	7-22-83	11-11-83	ibid.	ibid.	None		8 s./ 10 min.	91.3	34.4	50.3
	Nonstripped	504	7-22-83	11-11-83	ibid.	ibid.	ibid.		ibid.	90.3	27.7	58.1
Weigela florida 'Java Red'	Stripped	560	8-2-83	11-11-83	1000 ppm IBA	ibid.	None		8 s./ 10 min.	68.0	NC	NC
	Nonstripped	560	8-2-83	11-11-83	ibid.	ibid.	ibid.		ibid.	67.9	NC	NC
Berberis thunbergii 'Atropurpurea Nana'	Stripped	634	8- 4-83	11-11-83	Wood's 1-10	sand	None		high hmdty tent	46.7	6.8	12.0
	Nonstripped	634	8- 4-83	11-11-83	ibid.	ibid.	ibid.		ibid.	19.2	7.4	17.9

Table 1. Cultural information and the effect of stripping or nonstripping on rooting of woody ornamental cuttings. Data listed by nursery and species (continued).

Species	Cutting treatment	No. stuck	Date stuck	Date evaluated	Hormone treatment	Media	Duration of bottom heat and temperature Days	C	Mist	Percent rooting	Ave. no. primary roots *	Ave. no. secondary roots *
					VAN HOF NURSERIES							
Juniperus chinensis 'Hetzii'	Stripped	1,500	4-26-83	9-22-83	Wood's 1-5	sand	61	21°	8 s./ 6 min.	98	26	208
	Nonstripped	500	4-26-83	9-22-83	ibid.	ibid.	ibid.	ibid.	ibid.	72	11	215
J. conferta	Stripped	2,000	4-25-83	9-23-83	ibid.	ibid.	ibid.	ibid.	ibid.	84	17	152
	Nonstripped	500	4-25-83	9-23-83	ibid.	ibid.	ibid.	ibid.	ibid.	84	11	108
J. procumbens 'Nana'	Stripped	2,000	4-18-83	9-26-83	ibid.	ibid.	ibid.	ibid.	ibid.	49	8	118
	Nonstripped	500	4-18-83	9-26-83	ibid.	ibid.	ibid.	ibid.	ibid.	55	4	180
J. virginiana 'Grey Owl'	Stripped	2,000	4-14-83	9-28-83	ibid.	ibid.	ibid.	ibid.	ibid.	70	4	21
	Nonstripped	500	4-14-83	9-28-83	ibid.	ibid.	ibid.	ibid.	ibid.	48	7	52
J. horizontalis 'Abbey'	Stripped	600	4-13-83	9-29-83	ibid.	ibid.	ibid.	ibid.	ibid.	98	6	35
	Nonstripped	500	4-13-83	9-29-83	ibid.	ibid.	ibid.	ibid.	ibid.	46	19	86

* Average of 50 cuttings per treatment.
** Intermittent mist.
*** NC = Not Counted.

Late summer hardwood cuttings of *Juniperus horizontalis* 'Wiltoni' were stuck in flats and rooted under outside mist. Stripped cuttings rooted substantially better than nonstripped cuttings (Table 1). In addition, root systems of stripped cuttings were 10 to 20% longer.

Vern Black, Bailey Nurseries. Deciduous softwood cuttings were rooted in poly covered greenhouses. There were no significant differences in rooting percentages between stripped and nonstripped cuttings of all species propagated (Table 1). With the exception of *Spiraea* cuttings, nonstripped cuttings tended to have slightly fewer primary roots. However, regardless of the stripping treatment, root systems on all species were of acceptable size for planting.

There seems to be no real advantage to stripping softwood cuttings except for species with large leaves. Although stripping the lower leaves takes additional time, the increased time is offset by the increased efficiency in sticking stripped cuttings. Some plant species that we strip are *Cornus*, *Forsythia*, *Hydrangea*, *Lonicera*, *Syringa* (French cultivars), *Viburnum*, and most *Prunus* spp. Plant species we do not strip include *Euonymus*, *Physocarpus*, *Potentilla*, *Ribes*, *Spiraea*, and dwarf *Syringa* spp.

Dale Maronek and Daniel Studebaker, Studebaker Nurseries. Rooting percentages of stripped and nonstripped *Spiraea*, *Forsythia*, and *Weigela* cuttings were similar (Table 1). Only the rooting percentages of *Berberis* and *Juniperus* cuttings were affected by stripping treatment. Stripped cuttings of both of these species rooted nearly 50% better than nonstripped cuttings.

With the exception of *Forsythia* cuttings, stripping did not affect the overall size of the root systems on any deciduous species. The root systems of stripped *Forsythia* cuttings were visually larger than those on corresponding nonstripped cuttings. This was attributed to the larger number of primary roots formed on stripped cuttings (Table 1). However, the smaller root systems on nonstripped *Forsythia* cuttings were still of acceptable size for planting.

Stripping did affect the development of basal shoots on *Spiraea* cuttings. On 15 to 20% of all nonstripped cuttings, one to two shoots developed at the base of the cuttings. In contrast, none of the stripped cuttings had any basal shoot development. It would be of importance to determine if basal shoot formation on nonstripped cuttings had an effect on plant salability, especially as a liner.

Stripping treatments also had an effect on the pattern of root development and on root morphology of *Juniperus* cut-

tings. Roots of stripped cuttings were much finer and had more secondary roots than roots on nonstripped cuttings. The primary roots from nonstripped cuttings were thicker and quite brittle compared to those formed on stripped cuttings. A substantial number of these brittle roots broke off when the cuttings were potted. In addition, roots only formed from the basal end of the nonstripped cutting while root formation was fairly consistent up and down the stem of stripped *Juniperus* cuttings. Although not investigated in this study, root formation at only the base of the cutting could ultimately affect how the cuttings are potted and subsequent survival.

Ronald St. Jean, Van Hof Nurseries. All *Juniperus* cuttings were stuck in outside sand frame units and bottom heat was applied with electric cables set at 21°C for the first 61 days of propagation. Stripped cuttings of *Juniperus chinensis* 'Hetzii', *J. virginiana* 'Grey Owl', and *J. horizontalis* 'Abbey' rooted substantially better than corresponding nonstripped cuttings.

In contrast, nonstripped *J. conferta* and *J. procumbens* 'Nana' rooted substantially better than corresponding stripped cuttings. In general, all rooted cuttings had well developed root systems. The number of primary and secondary roots on stripped and nonstripped cuttings varied by species. However, regardless of the stripping treatment, fewer primary roots were often offset by an increase in the number of secondary roots.

We will continue to use nonstripped *J. conferta* and *J. procumbens* 'Nana' for both winter and summer production. Using nonstripped cuttings actually took more time since selection of cutting wood was restricted to thinly branched cuttings. Also, the smaller cuttings required more time to stick.

SUMMARY AND CONCLUSIONS

The results of this study indicate that the advantages of nonstripping versus stripping of cuttings should be determined on a species by species basis. In this study, root systems of most nonstripped cuttings were comparable to those of stripped cuttings. Consequently, the advantages of not stripping cuttings appear to be increased rooting and/or savings in labor. However, any labor savings as the result of not stripping cuttings may be partially or completely offset by a combination of factors. First, some propagators found it required more time to select cuttings of smaller size that didn't need to be stripped. Second, although man-hours were saved in the actual preparation of the cuttings, this was somewhat offset by the additional time reported by each propagator to stick the cuttings. Finally, nonstripped cuttings of some species required more bench space than stripped cuttings.

In addition, the results of this study also identified several areas which need to be examined more closely. The effects of decaying vegetative material in the propagation medium should be determined. Although none of the propagators experienced any difficulties in this study, decaying plant material could increase the spread of disease. In addition, decaying plant material could release plant toxins which may affect the rooting of cuttings. Finally, changes in root morphology should be closely monitored, since these may affect how the cuttings are handled during other subsequent nursery operations, e.g. lifting and/or potting of cuttings.

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CHARLIE PARKERSON: I have a question for all the panel members. Did you all stick your cuttings to the same depth for each treatment?

PANEL MEMBERS: Yes.

CHARLIE PARKERSON: A question for Ron St. Jean. Why did you select a smaller cutting for the nonstripped?

RON ST. JEAN: Because I was interested in equal bench density for the stripped and nonstripped.

CHARLIE PARKERSON: I do not think that yours was a fair test. We can not expect different sized cuttings to throw off the same number of roots.

PETER VERMEULEN: What method did each of you use to strip?

PANEL MEMBERS: Leaves were pulled off.

ED MEZITT: I am interested in the juniper cuttings. Were they all tip cuttings? We usually trim off the tips and make thicker cuttings because they give us more wood to root.

RON ST. JEAN: Yes, they were tip cuttings.

TOM MCCLOUD: Some of the *Juniperus horizontalis* 'Wiltonii' may have been mid-stem cuttings. Thick cuttings would provide more wood for rooting.

NORMAN TESSIER: Did you get a lot of debris in the sand from the nonstripped juniper cuttings? Did you use a fungicide?

RON ST. JEAN: It did not cause a problem and we did not use a fungicide.

PETER VERMEULEN: Ron, just for the record, there are two forms of *J. procumbens* 'Nana'. One came from D. Hill Nursery and the other from Europe. Many of the eastern nurseries use the European form. Is the one that you are using similar to *J. squamata* 'Prostrata'? It is important that we know this.

RON ST JEAN: Yes.

GERALD VERKADE: I am confused about the size of the *J. procumbens* 'Nana' cuttings. How long were they?

RON ST. JEAN: About 4 in long.

DAN STUDEBAKER: Ron, how did you introduce the *J. procumbens* 'Nana' into the medium?

RON ST. JEAN: We used a knife to draw a line and then stuck them.

DAN STUDEBAKER: What I am driving at is the following: I think we need to be sure to get good medium contact with nonstripped cuttings which can be difficult.

RALPH SHUGERT: I have two comments. First, just because we mention sticking the genus *Taxus* is not enough. You need to watch those cultivars and don't do your whole crop nonstripped; experiment with each cultivar. Second, in my opinion, we do not stick unstripped cuttings as deep in the bench. I think the shallower we can stick the cutting the better we are.

JAMES WILL: We have been sticking in July all our magnolia cuttings (*M.* × *soulangiana, M. stellata, M. salicifolia*) for the last 8 years without stripping. Many of the cultivars root 95 to 98% in outdoor sand beds. By not stripping, the cuttings are anchored better in the bed.

MARK RICHEY: I find that certain nonstripped cultivars require only ½ as much hormone, especially in the summer, or basal burn will result.

VOICE: I had the same problem with 'Crimson Pygmy' barberry cuttings, sticking them the same time you did. I took them early in July with ½ in. of last year's growth and found I could root a very high percentage with varying concentrations of hormone.

DALE MARONEK: Where did your roots form?

VOICE: Generally on the older .wood or the union of the two wood types.

JOERG LEISS: We also use old wood with excellent results in July.

SOMATIC MEIOSIS

R. J. GRIESBACH

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Beltsville, Maryland 20705

In order to obtain new genetic variability plant breeders have turned to wide hybridization. Wide hybridization is the process of obtaining progeny from crosses between distantly related species or genera. Wide hybridization could involve more classical approaches such as embryo culture (9) or some of the newer techniques of genetic engineering like electrically-induced cell fusion (13). In either case, a hybrid is produced which is likely to be intermediate in morphology between the two parents. Further breeding is generally required before a commercially valuable plant type is created.

In most instances wide-hybrids are sterile because of a lack of chromosome pairing during meiosis. This sterility can sometimes be corrected through chromosome doubling to create a type of polyploid called an amphidiploid. Amphidiploids, even though polyploid, behave like diploids in that only two of the potential four chromosomes in a set pair during meiosis (1).

Not all amphidiploids, however, are fertile. In the case of the interspecific hybrid *Lilium* 'Black Beauty' (*L. speciosum* × *L. henryi*), viable pollen was not produced until after the chromosomes were doubled. Five hundred and fifty pollinations with a very fertile amphidiploid *Lilium* 'White Henryi' (*L. henryi* × *L. leucanthum* var. *centifolium*) resulted in the pro-

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duction of only five seeds which contained viable embryos. Potentially, 100,000 viable seeds could have been produced. (R.A. Griesbach, personal communication)

Plant breeders would greatly benefit from a procedure for inducing a meiotic-like process in mitotic or somatic cells. In this way, it might be possible to obtain progeny from sexually sterile hybrids. Meiosis, although quite complicated, is simple in principle and can be subdivided into two distinct events — recombination and segregation. During recombination, genetic material is exchanged between the pairs of homologous chromosomes of each set. After recombination, the two chromosomes separate or segregate into different gametes. Recombination and segregation result in new gene combinations which are not found within the two parents. For example, one parent could have large red flowers and the other parent small white flowers. Their offspring might all have large red flowers. Because of meiosis some of the progeny obtained by crossing the hybrids would be expected to have either small red flowers or large white flowers, two new gene combinations.

MITOTIC RECOMBINATION

It is possible to induce mitotic chromosomes to undergo recombination. Considerable information is known about this process in fungi (6). In fungal cells, the spontaneous frequency of mitotic recombination is about 1000-fold less than the meiotic process. Many drugs or chemicals which inhibit DNA synthesis (eg. mitomycin C, fluorodeoxyuridine, hydroxyurea, etc.) or chemical or physical processes which break the DNA (e.g. ultraviolet light, ethidium bromide, x-rays, etc.) have been found to greatly increase the frequency of mitotic recombination, to levels found within meiotic cells. Studies in fungi have indicated that there are major differences between mitotic and meiotic recombination. First, mitotic recombination occurs more frequently in regions near the chromosome's centromere. The opposite is true for meiotic recombination. Second, mitotic crossing-over appears to be initiated at random sites within the genome; while meiotic crossing-over is believed to be initiated at specific sites. Finally, mitotic recombination, unlike meiotic recombination, does not require DNA replication.

One measure of the frequency of mitotic recombination in higher eukaryotes is the occurrence of twin spots on differentiated tissue. The outcome of a mitotic recombinational event is the production of two different cell types. At the end of a developmental sequence (eg. leaf development) each of the two recombinant cells will have given rise to a distinctive

group of cells. The two cell groups will be spatially next to each other and will appear as a double or twin spot on a leaf or petal. As in fungi, the application of 10 μg/ml mitomycin C to germinating soybean seed can increase the frequency of twin spots or mitotic recombination five-fold over the spontaneous rate (12). The spontaneous frequency of mitotic recombination was 0.54 twin spots per leaf. When mitomycin C was applied to broadbean root tips both homologous and nonhomologous chromosome pairing was increased (1). Homologous chromosomes are the pair of chromosomes which are identical. On the average, 45% of the exchanges induced by mitomycin C involved homologous chromosomes. Data suggested that pairing was initiated in regions of heterochromatin or repetitive DNA which were not specific to any given chromosome type.

MITOTIC SEGREGATION

One way of inducing mitotic segregation is through chromosome elimination or reduction. If one doubles the chromosomes number and then reduces it back to the original level, the outcome is the same as segregation. There are several means of increasing chromosome elimination in somatic tissues; p-fluorophenylalanine was one of the first drugs which was used for this purpose (5). Black currant cuttings treated with this drug showed that about 25% of the newly formed roots had cells which contained reduced chromosome numbers. In diploid fungi, culture medium supplemented with low levels of griseofulvin (eg. 20 μg/ml) could induce both chromosome reduction and chromosome recombination (4,7). The chromosome loss was complete but gradual in that it could take up to four weeks before stable clones were produced. About 93% of the clones were haploid; the other 7% were diploid mitotic recombinants.

Griseofulvin has been applied to cultured, diploid alfalfa cells (11). Low doses (150 μg/ml for two cell cycles) caused both an increase and decrease in chromosome number. About 30% of the cells had a chromosome number below the diploid level and about 60% had a chromosome number above the diploid level. Griseofulvin treatment appeared to induce chromosome loss by producing abnormally shaped cells which had extensive cytoplasmic extrusions and irregular cell plates during mitosis (8). Griseofulvin also acted as a potent, mitotic, arresting agent blocking cells at mitotic metaphase. The combination of these effects resulted in the production of minicells containing varying numbers of chromosomes.

Griseofulvin has also been applied to cultured cells from a petunia somatic hybrid (3). In this case, whole plants have

been regenerated from the treated cells. About 9% of the regenerated plants were affected by the drug. Of these 9%, 47% had a reduced chromosome number. Many of the affected regenerates initially expressed a very high degree of both leaf and flower variegation which disappeared over time. For example, one regenerate started out producing magenta flowers having over 500 white sectors per flower. After six months, this plant was stably producing solid white flowers. Approximately 0.1% of the sectors initially produced by this plant were twin spots or due to somatic recombination. The practical outcome of griseofulvin treatment was the production of fertile plants which had reduced chromosome numbers and new gene combinations for flower color!

CONCLUSION

It appears that there are several different ways in which an artificial process that leads to genetic recombination and segregation can be induced in somatic cells. A combination of several approaches might work the best. The major difference between the meiotic process and the mitotic process is that the meiotic process is very highly ordered and excecuted while the mitotic process appears to be more random.

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CLONAL PROPAGATION OF PERENNIAL PLANTS FROM FLOWERS BY TISSUE CULTURE[1]

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Abstract. Several herbaceous and woody perennial plants have been clonally propagated by tissue culture using the flowers as explants. Even tetraploid plants regenerated from callus from flowers seem to be genetically stable. Flowers from several *Rhododendron* species and cultivars regenerated plants on Anderson's medium. The epigenetic change from maturity to juvenility may take place in some flower tissues before the formation of an embryo.

The propagation of perennial plants by tissue culture, particularly woody plants, has lagged behind the propagation of herbaceous annual and tropical plants. There are several reasons for this. First, obtaining a sterile explant can be a problem. Then, the problem that propagators have long recognized as loss of juvenility is magnified when we propagate perennial plants by tissue culture. Finally, there is the worry that genetic or even epigenetic changes will cause the plants to vary from the clone of interest. The following discussion will cover some of the advantages of using the flower parts of perennial plants as an explant source for tissue culture propagation in relation to these problems.

We should first examine some of the anatomical similarities and differences between vegetative and flowering growth of the terminal meristem. This phenomenon is covered extensively in Esau's classic anatomy textbook (6) and Gemmell's monograph (8). The vegetative meristem initiates stem and leaves in a very ordered pattern by growth protuberences at regular intervals on the flanks of the meristem. In the axils of

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the leaves new vegetative meristems or side buds are initiated which can grow into side branches.

The vegetative meristem turns into the flower meristem by an epigenetic process (14). This means the meristem has the same genetic material, but a different set of physiological and morphological genes are expressed when the flower organs; sepals, petals, stamens, and pistils are initiated. The flower parts, according to some theories, are modified leaves. The sepals, which are first initiated by the floral meristem, are green and leaf-like and grow up and cover the flower bud. The petals, which are initiated next, are usually devoid of chlorophyll but contain other pigments in some instances, and in others are devoid of all pigments (white). The stamens, the male sexual parts, are formed next. The anthers of these contain cells which undergo meiosis (reduction division) to form male haploid spores or pollen grains. The pistils are initiated last in the center of the flower and have an ovary which encloses one to many ovules. The ovules have cells which become the female spores. The female spores grow into the embryo sac contained in the ovule. All the flower structures are formed by mitotic divisions. This means that any flower part not concerned with the sexual cycle is developed by mitotic divisions and is capable of regenerating a plant similar to the plant that bears the flower. The sexual portion is usually only a small part of a mature flower.

The vegetative meristem, before it turns into a flower meristem, often makes several modified leaves (bud scales) or a single leaf (sheath). These structures grow up over and protect the floral parts until flower development is complete. This is usually done when the meristem initiates several individual flowers before it terminates its growth. These structures or the sepals make the floral parts very easily disinfested, even when the meristem is borne underground as in the case of many of the herbaceous perennials.

Since the regeneration of plants from tissue of mature plants has been found to be more difficult than from seedling plants (9,20), we might expect flowers to be a poor explant for tissue culture propagation purposes. However, there are several reports, including mine, which have found flowers to be an excellent source of explants for tissue culture propagation. I will review the methods and results of a few of these studies on perennial plants. I will then speculate why we can clonally propagate plants from flower explants by tissue culture.

The orchids were the first plants to be successfully propagated as clones by tissue culture techniques. Arditti (4) lists nine genera of orchids which are propagated using the flower

as the explant. Some of these orchids are propagated by stimulation of vegetative growth from nodes on the flower stalk. Other genera will develop callus from the flower parts which will form protocorms similar to the orchid seed germination process.

The ovule, or the nucellar tissue of the ovule, surrounding the sexual embryo sac seems to be a good source for regeneration of embryos by tissue culture. A recent review (23) lists 15 species of *Citrus* and 5 related genera showing this phenomenon. This phenomenon is also apparent in the mango (13). Other papers (11,22) report this regeneration to take place in grape cultivars which are quite old. The nucellar tissue in some flowers will form embryos on the plant without tissue culture and causes polyembryony with apomictic embryos (9). Either process could be considered clonal propagation.

I have had success with several herbaceous perennials (15, 16, 19) by excising flower tissue and culturing it with the appropriate growth regulator treatment in the dark until it develops masses of callus. These callus masses when divided and subcultured in the light will develop large numbers of plants. These techniques have even been used to clonally propagate tetraploid plants (15, 19). It has also been possible to clonally reproduce and separate a chimeral *Hosta* using the flower as an explant (16).

Other workers have developed callus from flowers into shoots from more woody species. Bennet and McComp (5) reported success with *Eucalyptus marginata* from stamen filament callus. Hearne (10) reported a successful technique with passion flower. The immature female flowers of *Salix tetrasperma* were found by Angrish and Nanda (3) to make vegetative shoots directly from the flowers. Some of the leaves of these vegetative shoots had stigmatic surfaces on the tips.

Plants of the genus *Rhododendron* have been propagated more widely than any other landscape plant. These have been mainly by shoot tip proliferation with the medium developed by Anderson (1) and commercially developed as reported in a paper by Kyte and Briggs (11). I have found that Anderson's medium works well using the flowers as explants (17, 18). Several species and cultivars of *Rhododendron* at several times during the dormant season have been propagated in substantial quantities (Table 1). The flowers are very easily extracted in a sterile condition from the dormant flower bud, as the resinous bud scales form a protective covering for several individual flowers.

The individual flowers with as much pedicel as possible are placed on Anderson's medium in the dark until there is

substantial callus-like growth. Flowers of two clones of 'Northern Lights' deciduous hybrid azaleas seem to respond better to 12 mg/l zeatin than to the 15 mg/l of 6-(gamma, gamma, dimethylallyamino)purine (2iP) of Anderson's medium. Zeatin was also found by Fordham *et al.* (7) to be superior for Exbury azalea shoot tips. The growth occurs from the base of the flower and the pedicel. When the callus-like masses are subcultured in the light on Anderson's medium with the growth regulator lowered, substantial quantities of shoots are formed. These can be rooted using standard transfer techniques (2). The plants formed are juvenile in nature with small rounded leaves and will grow continuously if kept under long days and high moisture and fertility (18).

Table 1. Tissue culture propagation of several species, cultivars and hybrids of hardy *Rhododendron* from flowers.

Species and Cultivar	Dates of Init.	Ease*
R. 'Nova Zembla'	4/28, 10/10	++
R. 'Sefton'	2/5, 3/27	+
R. 'Roseum Elegans'	2/18, 3/19, 9/17	−
R. catawbiense 'Album'	4/17	−−
R. 'Sefton' × *R.* 'Purple Splendour'	8/24	+
R. 'Abraham Lincoln'	8/24	−
R. 'Vulcan'	10/10	−
(R. carolinanum × *R. dauricum)* × *R. dauricum* 'White'	9/14	−
R. kosteranum × *R. prinophyllum* 'Northern Lights S'	1/21, 3/23	+**
R. 'Northern Lights M'	3/23	−−

* Relative ease of propagation: ++, easy; −−, difficult.
** Zeatin 12 mg/l better than 15 mg/l 2iP.

One of the first scientific papers brought before this Society was by F. L. S. O'Rourke (21) on the effects of juvenility on plant propagation. This juvenility phenomenon has been even more severe for propagation by tissue culture (9, 20). In botanical terms the end product of the ontogenetic change from juvenile to mature form is the formation of flowers. The above discussion gives several perennial plants that can be clonally propagated by tissue culture from flowers and this would seem to be a contradiction. It is a tacit assumption that the reinitiation of juvenility is the combination of the egg and sperm to form a zygote which grows into a plant embryo. However, this does take place in the flower and the flower tissue must transport all the metabolites needed for the development of the zygote to the embryo stage or to develop the endosperm for this purpose. Since the flower formation involves a considerable epigenetic change over mature vegetative growth, the flower may not be the end of the maturing process but the

beginning of the reinitiation of juvenility. Perhaps the flower is the transitional phase in the mature to juvenile change. It would appear this way from the above tissue culture work. *Rhododendron* flowers would be a good example of this where the petal and ovary base and even the pedicel reinitiates shoots with juvenile characteristics. The flower may be the easiest explant source for formation of juvenile tissue needed to propagate clones by tissue culture that lose juvenility at a young age, as in many woody plants.

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GRAFT INCOMPATIBILITY IN WOODY PLANTS

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Grafting is an old method of plant propagation and since ancient times propagators have been aware of the problem of scions failing to make satisfactory growth when budded or grafted to an understock. Compatibility is defined as the ability of two different plants, when grafted together, to produce a successful union and develop satisfactorily into one composite plant (5). The opposite, failure to develop satisfactorily, is called incompatibility. Several excellent reviews on stock-scion incompatibility have been published by Argles (1), Hartmann and Kester (5), Mosse (10), and Nelson (11). The publication by Nelson (11) in our Proceedings is particularly important for plant propagators because of the extensive number of ornamental graft combinations surveyed and reported on in tabular form. However, just what constitutes graft-incompatibility has presented difficulties because many of the symptoms are nonspecific and similar to those which can be caused by unfavorable environmental conditions, viral infection, desiccation of the tissues, or poor techniques. Also, incompatibility can take numerous forms from slight symptoms of ill-health to complete graft failure when no union is formed.

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SYMPTOMS OF INCOMPATIBILITY

Garner (3) proposed that incompatibility should be reserved for distinct failure to unite in a mechanically-strong union, failure to grow in a healthy manner, or premature death, when such failure can be attributed with a reasonable degree of certainty to differences between stock and scion. Moore and Walker (8, 9), however, define incompatibility in a more restricted sense as mutual physiological influences (or lack of them) between tissues of the stock and scion that ultimately result in an unsuccessful graft. Such a restricted definition more realistically describes true incompatibility, I feel.

Mosse (10) divided graft-incompatibility into translocated and localized types and proposed that the two types corresponded to some fundamental difference in underlying causes. The following summarizes the main distinguishing features of the two types:

1. Translocated
   a. Accumulation of starch above and its almost complete absence below the union.
   b. Phloem degeneration.
   c. Different behavior of reciprocal grafts.
   d. Normal vascular continuity at the union.
   b. Early effects on growth.
2. Localized
   a. Characteristic breaks in cambial and vascular continuity.
   b. Similar behavior of reciprocal combinations.
   c. Gradual starvation of the root system, with slow development of external symptoms proportional in severity to the degree of vascular discontinuity at the union.

CAUSES OF STOCK-SCION INCOMPATIBILITY

Although graft incompatibility is related to mutual physiological influences, whether positive or negative, between cells of the rootstock and scion, the underlying cause(s) leading a particular combination to succeed or fail is unknown. Therefore, successful graft combinations through history have been determined by trial and error.

At an anatomical level, Moore and Walker in a recent series of publications (8, 9) investigated the compatibility reaction in a system known to be obviously incompatible, *Sedum telephioides* and *Solanum pennellii*. Several major structural events were shown to occur during the ontogeny of the compatible graft (*Sedum* autographs). Initially, ruptured cells at the

graft interface collapse and form a necrotic layer that separates the graft partners. By 6 hours, a pronounced accumulation of dictyosomes was noted along the cell walls adjacent to the cut surface and adhesion of stock and scion was detectable soon after. Adhesion of the stock and scion appeared to result from the activity of the dictyosomes that secreted materials into the cell wall space at the graft interface. Cell divisions ruptured the necrotic layer by 2 to 3 days. Procambial differentiation occurred across the graft union by 10 to 14 days. A similar pattern was noted earlier in coleus autographs by Stoddard and McCully (12).

Major structural events occurring during the ontogeny of the incompatible heterograft (between *Sedum* and *Solanum*) were similar to the *Sedum* autographs during the initial 24 hour period. However, *Sedum* cells adjacent to the graft union subsequently deposited an insulating layer of suberin along the cell walls and ultimately underwent a lethal cellular senescence. Moore and Walker concluded that cellular senescence in the heterograft resembled the hypersentitive response induced by plant pathogens and may be an example of a cellular defense mechanism or toxicity response.

At the biochemical level, the only incompatible graft that has been characterized is the pear/quince system. Gur *et al.* (4) showed that the anatomical disturbance at the union resulted from the seasonal inactivation of the cambium, due to cyanide liberated from the hydrolysis of prunasin near the graft union.

At Penn State University I have been conducting biochemical studies on vegetative compatibility in *Prunus* species. The *Prunus* stock-scion incompatibility systems were selected because their compatibility relationships have been well documented (1, 5, 10). In addition, they contain prunasin, already known to be responsible for graft failure in the pear/quince graft, and this compound could be utilized to test the hypothesis that vegetative incompatibility is a toxicity response. A problem in conducting studies on graft incompatibility is that potentially toxic compounds cannot be administered under controlled conditions. Callus cultures provide a unique system for investigating factors regulating plant growth and development and were adapted to study graft incompatibility. Complications resulting from microbial contamination and nutritional and environmental variations are eliminated. In addition, callus cultures allow for the incorporation of compounds under controlled conditions.

I have found that prunasin can inhibit the growth of a number of *Prunus* species. For example, in the almond/'Mar-

ianna 2624' graft combination, the almond cultivar, *P. amygdalus* 'Nonpareil', forms an incompatible union (7). When prunasin is added to callus cultures from both plants, the growth of 'Marianna 2624' is differentially inhibited (Table 1).

Table 1. Fresh weight (mg/callus) of 'Marianna 2624' plum and 'Nonpareil' almond callus.

	Prunasin concentration (mM)	
Plant	0	1
'Marianna 2624' plum	928.7	20.3
'Nonpareil' almond	2,676.4	2,476.6

Cyanogenic gylcosides, such as prunasin, do not directly cause the incompatibility reaction but must be decomposed to release a toxic product (4). The enzymatic hydrolysis of prunasin proceeds in a two-step process: prunasin is hydrolyzed to mandelonitrile and glucose; and mandelonitrile is hydrolyzed to hydrocyanic acid and benzaldehyde. The decomposition product hydrocyanic acid has been shown to cause the anatomical disturbance at the union of the incomptabile pear/quince combination (4). I have demonstrated that Nanking cherry *(P. tomentosa)* and sand cherry *(P. besseyi)* callus cultures have a greater sensitivity to cyanide than do peach *(P. persica)* callus. Callus growth of both cherry species was very severely inhibited by concentrations in the order of 1 mM cyanide. Growth inhibition in peach was mainly a reduction in fresh weight, with little reduction in dry matter (Figs. 1 and 2). Both cherry species are dwarfing understocks for peach and are known to have stock-scion incompatibility problems with peach.

In conclusion, prunasin and its toxic breakdown product, hydrocyanic acid, are capable of inhibiting the growth of callus from understocks known to exhibit vegetative incompatibility, and this suggests that cyanogenesis may be a causal factor in *Prunus* stock-scion graft failures.

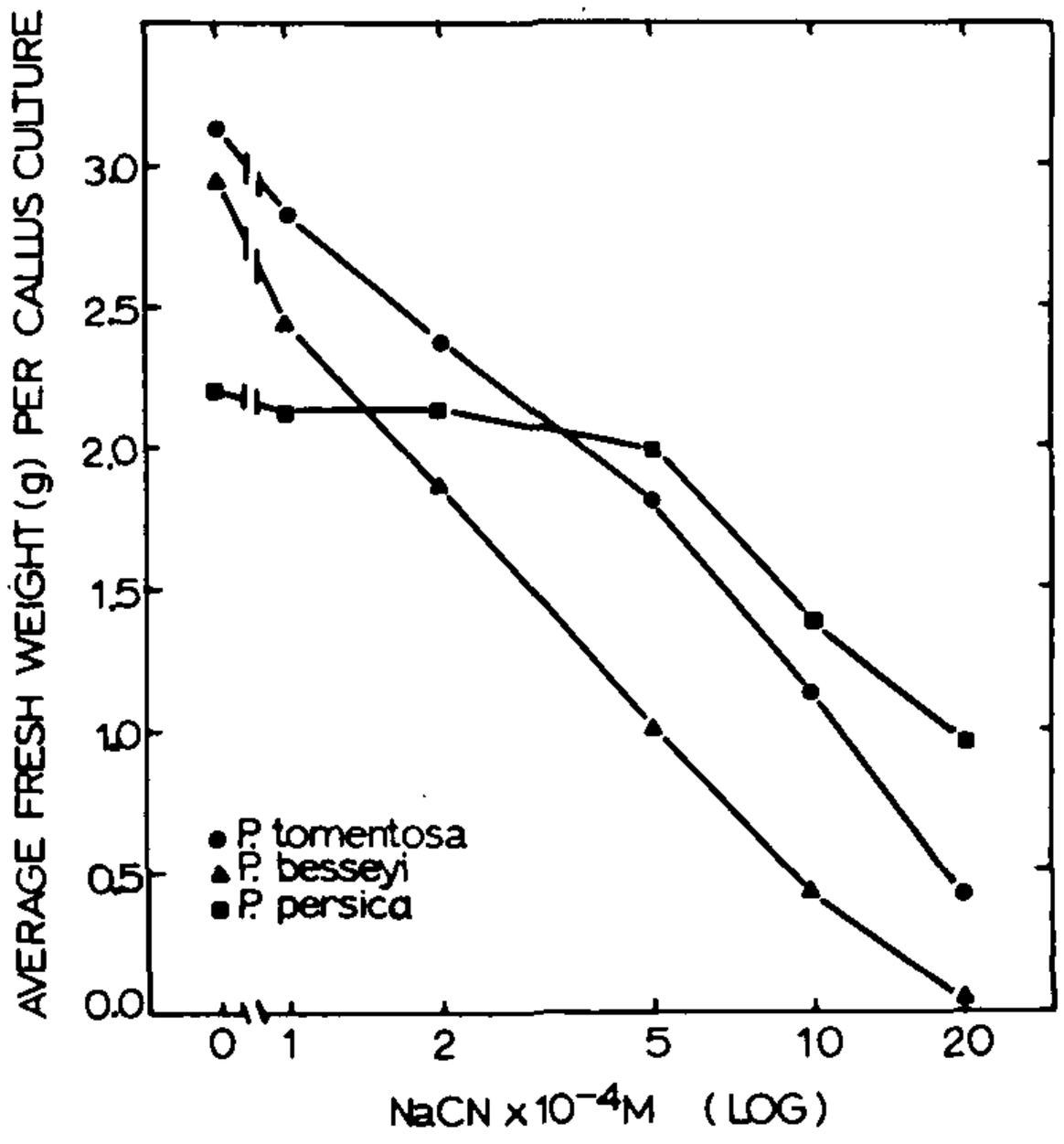

Figure 1. Influence of sodium cyanide concentration on fresh weights of *Prunus persica*, *P. tomentosa*, and *P. besseyi* callus cultures.

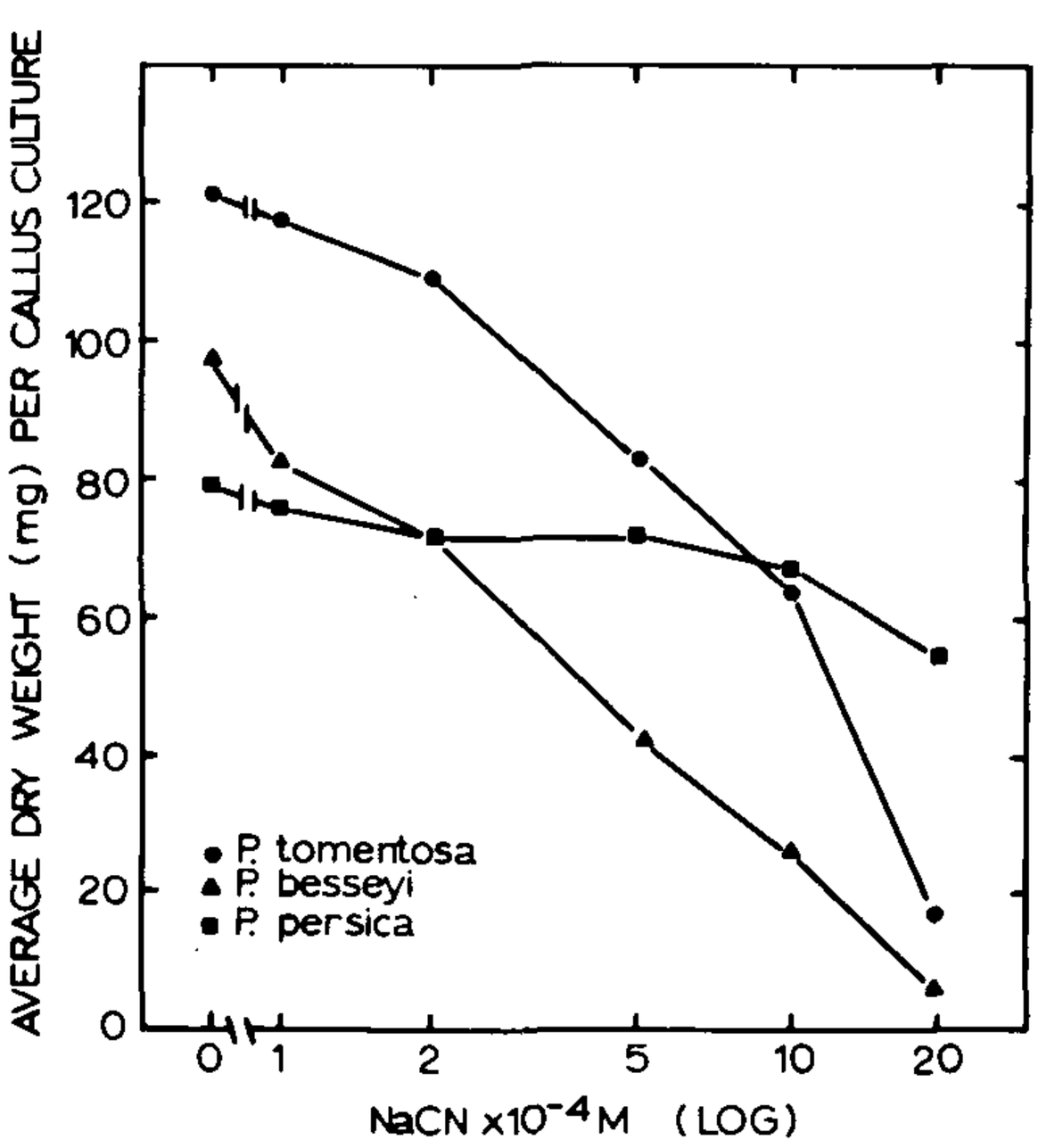

Figure 2. Influence of sodium cyanide concentration on dry weights of *Prunus persica*, *P. tomentosa*, and *P. besseyi* callus cultures.

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THE USE OF PRE-EMERGENCE HERBICIDES TO CONTROL CHICKWEED IN NEWLY-BUDDED CRABAPPLES

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The dormant buds on newly-budded crabapple trees are susceptible to injury or even death if they are smothered by common chickweed *(Stellaria media)* during the winter and in the early spring. The chickweed can grow over the bud, shutting out light and reducing air movement around the bud. There are many preemergence herbicides that will control

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common chickweed, but the effect of these herbicides on the growth and development of the bud into a saleable crabapple tree is not known. For this reason an evaluation of several preemergence herbicides for control of chickweed and their effect on the growth of newly-budded crabapples was made.

MATERIALS AND METHODS

Test plots were established at a commercial nursery in Vincennes, Indiana, on September 16, 1982. Buds of *Malus* 'Indian Magic' were budded on spring-planted apple rootstocks in August, 1982. At the time of treatment the buds were dormant but the rootstock was in full leaf.

The herbicides and rates used are given in Table 1. Application was made with a CO_2 powered sprayer delivering 27 g.p.h. of spray at 30 p.s.i. in a 30 in. band. The herbicides were applied to the base of the trees and the new bud union. Environmental conditions at spraying were clear sky, air temperature was 69°F, and soil surface temperature was 70°F, with a light 10 mph wind.

Table 1. Herbicides and rates used for chickweed control

Common name	Trade name	lb/A product
oryzalin	Surflan	2⅔ & 5⅓
diphenamid	Enide	8 & 16
DCPA	Dacthal	8 & 16
napropamide	Devrinol	8 & 16

A randomized complete block design was used with 3 replications. Weed control ratings were made on November 15, 1982 and March 30, 1983. Also on March 30, 1982, weed biomass was sampled from a one square foot area of each plot. Normal weed control practices in the nursery were followed after March 30, 1983 and included cultivation and hand hoeing of the plots. On November 18, 1983, the trees were harvested with the bare-root tree digger, all the soil was removed from the roots, and the trees were placed in storage. On November 22, 1983, the average fresh weight per tree, the height from the bud union to the main shoot tip, and the root vigor of 10 trees from each plot were determined.

RESULTS AND DISCUSSION

The herbicides varied in their effectiveness for controlling chickweed (Table 2). The initial weed control rating showed that the high rate of oryzalin provided the best control while diphenamid at either rate was nearly as good. Long term control with both rates of oryzalin was satisfactory until March, 1983, with the high rate giving 100% control. The high rates of

diphenamid and napropamide gave nearly as good control as the oryzalin treatments (Table 2). Weed weights for all weed species present indicated there were no differences among the oryzalin, diphenamid, and the high rate of napropamide and DCPA treatments, and that these treatments were superior to all other herbicide treatments (Table 2). However, visual observations indicated that the oryzalin treatments were superior to all others.

Table 2. Effectiveness of herbicides in controlling weeds.

Treatment		Percent control of chickweed		Total weed growth
Herbicide	lb/A	11/15/82	3/30/83	g/sq ft
check	0	0	0	271 ab[1]
oryzalin	2⅔	67	88	43 d
oryzalin	5½	92	100	41 d
diphenamid	8	82	68	85 d
diphenamid	16	80	95	140 bcd
DCPA	8	37	0	274 abc
DCPA	16	78	73	62 d
napropamide	8	40	23	323 a
napropamide	16	72	88	116 cd

[1] Numbers followed by the same letter are not significantly different at the 5% level

No herbicide treatment adversely affected the growth of the crabapples. There was no effect on the survival and development of the buds (data not shown). Average weight per plant in all herbicide treatments was equal to or better than in the check. Also, the height and root development of trees in the herbicide treatments were comparable to that of trees in the untreated check (Table 3).

Table 3. Growth of crabapple when treated with preemergence herbicides for chickweed control.

Treatment		Height	Root	Weight
Herbicide	lb/A	(inches)	rating[1]	oz/tree
check	0	51.2	3.7	10.9
oryzalin	2⅔	48.4	4.3	11.9
oryzalin	5⅓	54.1	4.3	13.6
diphenamid	8	52.4	4.0	16.3
diphenamid	16	53.0	4.0	14.6
DCPA	8	59.2	5.0	22.5
DCPA	16	58.3	4.3	20.9
napropamide	8	58.5	4.3	17.7
napropamide	16	58.9	4.3	18.0

[1] Rating: 1, poor to 5, best

CONCLUSIONS

Chickweed was effectively controlled by use of preemergence herbicides and there was no effect on subsequent growth of the budded crabapples. Also, bud survival was not

affected. Oryzalin at 2⅔ lb/A provided very satisfactory control, while high rates of diphenamid, DCPA, and napropamide also controlled chickweed, but the use rates of these herbicides was higher than that recommended on the product label.

JAMES COARTNEY: Why did you not use a low rate of Princep which would be effective and enhance any of those materials?

PHILIP CARPENTER: The nursery wanted us to use the minimum amount of herbicide and we thought we could do without it. We have been very satisfied with Princep plus Surflan in the fall with very good results.

RALPH SHUGERT: Is there a reason why you did not use Kerb?

PHILIP CARPENTER: We primarily look at Kerb as a perennial grass killer.

RALPH SHUGERT: But it will work on chickweed at 2 lb AIA.

AN INEXPENSIVE METHOD OF DWARF SPRUCE PROPAGATION

DAVID H. BAKKER

J. C. Bakker & Sons Limited
RR # 3, 3rd Street South
St. Catharines, Ontario, Canada L2R 6P9

Dwarf spruce, such as *Picea glauca* 'Conica' and *Picea abies* 'Nidiformis', are slow growing conifers which are also slow to root from cuttings. To propagate these unique plants many methods have been used: summer-winter cuttings, grafting, mist, etc. We use a method which is easy to do, easy to maintain, takes no added heat, uses no misting, and the structure is economical to build. A cold frame with sash is used (no plastic) inside a shade house which has snowfence for shade covering (40% shade). The cold frame must have the sash absolutely tight fitting.

The rooting medium used is a sand-peat mixture with the fine washed sand (plaster type) put on a level bottom of top soil of a sandy nature, then the peatmoss is applied over the top of the 6 in. fine sand layer. The peat moss (2 in.) is watered and throughly mixed with the fine sand. The top of

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the medium mixture, after leveling, should be about 4 to 6 in. from the sash.

Cutting maturity at harvest is very important. A good date in our area is approximately July 4th; however this may vary from place to place. Actually, the time is when the mother plants begin their second flush of growth. Cuttings taken too early result in basal decay.

Cuttings are gathered from field-grown plants (not from "old mamas"), dipped in water, and put in baskets which are kept under plastic in the cutting room. It is wise to gather fresh cuttings each day. They are stripped of the small branches but not needles, and made with a heel. The heel is trimmed to just below the basal buds with about 1/16 in. of old (previous year) wood remaining on the base of the cutting. Too much old wood will cause failure, but no old wood will give basal decay.

No hormones are used. Dutch researchers ran many tests which showed that any method or combination of IAA, IBA, NAA failed to give better rooting than no hormone, and they sometimes retarded rooting.

Cuttings are 2 to 3 in. long and are inserted ½ to ¾ in. deep in the propagation medium. They are fine-misted from time-to-time at the table where they are made and during sticking. Sash and white shade cloth are drawn over the cuttings as they are stuck. The cuttings are firmly packed with a hammer and 2 in. board. Row spacing is 2 in. apart and the cuttings are set ½ in apart. They are throughly watered in at the end of the day. A sash area of 6 × 3 ft. holds approximately 2,500 cuttings. Moisture content is checked the next day. No further watering is needed during the summer. However, at 2 week intervals the cuttings are checked.

The white shade cloth remains over the sash until the summer temperature starts to drop in September, when most of the rooting starts to take place. The worst take we have had is 50%, the best 90%, and 75% is the most common take. A double layer of sash and some snowfence is put over for winter protection and heaving. In the spring the winter protection is removed, but the sash stays on and new growth begins rapidly ahead of the season. Some unrooted cuttings will still root even then.

When the first flush is hardened off, the sash is removed and the rooted cuttings are liquid fertilized every 10 days (a high nitrate, acid fertilizer). The rooted cuttings are left in the cold frame for two summers and are then planted with a 5-row bed planter at a 7 × 10 in. spacing. After two seasons in the bed they are sold as 10, 12, 15 in. lining-out material, contain-

erized, or planted out in the field. Another 2 years will give a 18 to 24 in., or 24 to 30 in. Alberta spruce, and a 12 to 15 in., or 15 to 18 in. nest spruce.

You will notice that this method took no flats or no small pots, as all plants were machine-planted in beds and in the field; no mist, no heat, no hormones, only time.

HENRY KOCK: What was your percent shade cloth?

DAVE BAKKER: I am not sure but we just buy bed sheeting by the yard and it will be the correct amount of shade.

PETER VERMEULEN: Could you give us some information on the age and size of your parent plants?

DAVE BAKKER: We learned that the hard way after setting up a stock block. The cuttings from the stock block did not root as well as when we take them from plants that are ready for sale that year.

Tuesday Evening, December 6, 1983

Mike Young moderated a group of presentations on grafting, including demonstrations. The following papers by Mike Young, Peter Vermeulen, Leonard Savella, and Tom McCloud were part of that session.

REVIEW OF GRAFTING

MIKE J. YOUNG

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Grafting is one of the oldest known forms of plant regeneration. References to it have appeared in writings for well over 2000 years. Over time it has become a valuable means of propagating many woody perennials as well as some herbaceous plants. Techniques in common use today are, in most respects, the same as those employed over the past several hundred years.

Grafting refers to the process of joining parts of two or more plants in such a way that they will unite and grow as one. The stock is the part of the new combination which will produce the root system and, occasionally with trees, the trunk as well. The scion is the part joined to the stock which will produce the top of the plant.

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There are many reasons for propagating plants by grafting. From the standpoint of the nurseryman and ultimately his customers, three are of particular importance:

(1) Perpetuation of clones which cannot be easily or economically increased by cuttings or other vegetative methods.

(2) To obtain the benefits of certain stocks such as disease and nematode resistance, size control, and cold hardiness.

(3) To obtain special growth forms, as the "weeping" form of certain upright growing ornamentals.

With time, practice, and patience the various methods of grafting can be mastered by most persons. Regardless of the technique used, however, five basic requirements should be met to maximize success:

(1) The stock and scion must be compatible with one another, therefore capable of uniting as one. In general, the closer the botanical relationship between the two plants to be joined, the greater the probability of obtaining a successful union. However, it should be emphasized that botanical relationships are based primarily on reproductive (flower, fruit) and not on vegetative characteristics. The chances of successfully grafting two members of the same species is very high, between species good, and between genera rather low by comparison.

(2) The vascular cambia of the stock and scion must be brought into close proximity with one another, preferably making contact, and held tightly together. The existence of a continuous vascular cambium in dicots and conifers and its absence in monocots is a very important reason it is used commercially only with the first two groups of plants. The freshly cut surfaces of both stock and scion must be capable of producing the callus tissue necessary for formation of the union. When using stocks with an intact and functioning root system, most of the callus formed will originate from it and not the scion. Callus growth is followed by formation of a vascular bridge and reestablishment of vascular continuity between the two.

(3) Buds on the scion should be dormant and remain so until healing has occurred. Depending on the technique used, the rootstock may or may not be dormant.

(4) Exposed cut surfaces must be protected from drying out and entry of decay-causing microorganisms prevented. This is accomplished with soil, or various wraps or waxes depending on the technique.

(5) Grafted plants should be given special attention for up to one full growing season or more after scions begin to grow.

This includes cutting or removal of wrapping materials, removal of suckers on the stock as they appear, and staking or otherwise supporting the newly-developing scion shoot(s).

Many nursery plants are grafted by joining a scion to roots from plants which had been previously dug in the field. If the root system is large enough, then individual pieces of sufficient diameter can be cut up and used. Each root piece is then grafted individually to a scion of similar size and length (piece-root grafting). If not large enough to subdivide, then the entire root system can be grafted to a scion (whole-root grafting). Since root grafting usually takes place indoors on tables in the winter months, it is often called bench grafting. Established plants in the nursery row or in containers are commonly crown or top-grafted. In the latter case scions are usually inserted into the stock from 10 to 20 cm above the soil line.

The many techniques of grafting developed over the years can be grouped into two categories. The first is approach grafting whereby the parts which will become the scion and stock are not cut from the parent plants until a union has formed. True approach grafting is sometimes used by nurserymen for plants which form a union very slowly. The second category is detached scion grafting, techniques of which are commonly used by nurserymen. With apical grafting techniques such as the whip, cleft, and saddle, the stock and scion are joined end-to-end. In inlay (veneer) and side grafting the scion is inserted on the side of the stock.

Two types of rootstocks are used in the nursery industry. The first, *seedlings*, have several advantages. They are relatively simple and economical to grow, rarely retain pathogens — especially viruses — occurring in the parent plant, and usually develop a deeper and more firmly anchored root system. Unfortunately, from the standpoint of propagation, horticultural plants are mostly heterozygous and their seedlings, therefore, will not consistently perpetuate desirable characteristics of the cultivar. There are several ways this variation can be minimized, however, and often it does not represent a serious problem to overall growth and longevity of the grafted plant. The second type, *clonal rootstocks*, are vegetatively propagated by layering or rooting cuttings. Therefore, each rootstock plant is genetically the same as all others of the clone and desirable characteristics are perpetuated intact. Although more expensive to produce than seedlings, consistent performance with respect to size control and disease resistance usually justifies the extra cost. In propagating and utilizing clonal stocks, the importance of using disease-free plant material when available cannot be overemphasized. Diseases occur-

ring in a mother stock plant will unavoidably be spread to all its propagations.

If a suitable environment is provided, grafting can be done at any time of the year. However, limitations dictated by economics and normal plant growth cycles result in the use of particular techniques only during certain times of the year. Generally, scionwood consists of the previous seasons' growth with healthy axillary buds. Watersprouts, when available, provide an excellent source of scionwood for many plants. Regardless of the technique used and time of year performed, it is essential that scion buds remain dormant until healing occurs. Therefore, conditions favoring callusing and healing of the graft union should not result in rapid growth of these buds. This may necessitate collection and cold storage of scionwood for some time prior to its actual utilization. Under environmental conditions favorable for growth, non-dormant buds on scions will grow for some time, whether a union forms or not. Unable to continually extract enough water from the scion though, they will soon die if sufficient growth precedes formation of the union and reestablishment of vascular continuity between stock and scion. In addition, moisture removed from the scion by rapidly elongating buds would otherwise be available to aid callusing and healing of the graft union. Usually, sufficiently rapid callus formation can be attained at temperatures below that which stimulate rapid bud activity.

Relative growth activity of the stock dictates in part the technique that can be used. Whip and cleft grafting techniques are more easily performed when both stock and scion are dormant and the bark adheres tightly to the wood. When actively growing, the bark often pulls away from the wood during the cutting operation. In contrast, the bark graft can only be performed at times of the year when the stock plant is actively growing and the bark is "slipping". Bench grafting is done during the late fall-early winter period due to the availability of roots from recently dug plants. With the overall view of producing a saleable plant at the end of the growing season, most forms of nursery grafting are done during the winter months when other nursery activities are minimal. After grafting, callusing and, if necessary, artificial chilling, the new plants are lined out in the nursery row in early spring. Depending on the plant, sufficient growth usually occurs in one growing season so that they can be dug and sold in the fall. In some cases, it is necessary to carry them on through a second growing season in order to attain adequate size.

Scions used in grafting usually are long enough to include 2 to 4 buds. In contrast, techniques of grafting in which the scion has only one bud are called budding. In fact, most nursery plants, especially fruit trees, are produced by budding. Most techniques of budding depend on an actively growing stock plant with slipping bark. In shield (T) budding the bark of the stock is cut in such a way that a broad face of cambial and other vascular cells capable of callus formation are exposed. Callus formed from these cells and those on the underside of the scion merge and form a union. Therefore, shield and patch budding techniques can only be performed during the growing season. In the dormant season chip budding can be used. With this technique cuts are made sufficiently deep into the stock to expose two thin lines of cambia. Similar thin lines of cambia on the underside of the cut scion must be aligned with those on the stock for healing to occur.

The scion used in budding normally consists of a bud with varying amounts of bark tissue surrounding it, depending on the technique. In shield budding, the scion is prepared so that a thin sliver of wood remains on the underside. The scion with the "wood in" is inserted into the stock, the wood giving it a degree of rigidity. Alternatively, this sliver of wood can be removed ("wood out") so that the underside of the scion as well as the stock will have broad cambial faces exposed to one another. Although the rate of success of one compared to the other is debatable, a scion with the "wood out" is more pliable and often easier to insert into smaller diameter stocks.

Regardless of the technique employed, adequate knowledge of the plant materials to be used and conditions necessary for success are indispensable in insuring a high degree of proficiency in grafting. As has been the case for many years as a method of propagation, it remains a valuable means of producing many important horticultural plants.

SIDE VENEER GRAFTING

J. PETER VERMEULEN

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P.O. Box 267, Woodfern Road
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At our nursery we primarily use the side veneer method of grafting. Most of our grafting is done in January and February, sometimes into March. Grafts made in the workshed are finished in two separate greenhouses, each with different micro-climates, one for conifers and the other for deciduous plants. The greenhouses are zone controlled for regulating temperatures for the differing requirements, (1) of the medium into which the pot and graft union are plunged (buried), and (2) the ambient air surrounding the tops, the latter being the cooler. We make approximately 50,000 grafts a year.

Understocks are potted well in advance of grafting time to permit good establishment. The recommended practice is to use dormant, sturdy, straight-stemmed seedlings between ⅛ and ¼ in. in diameter. They should have good fibrous roots. In some species these requirements will be found in a one-year (1-0) seedling but, most generally, a two-year (2-0) seedling is used. Occasionally, a 3 year (3-0) or a once-transplanted seedling (2-1) is used.

At the time of potting the roots and top of the seedlings are pruned. Roots are pruned to encourage development of a more branched and fibrous root system as well as to permit easier potting. The tops are pruned in order to reduce transpiration and to permit easier handling by the grafter. Branchlets on the lower portion of the stem where the actual grafting occurs must be removed. Commercial grafters generally use a 2¼ in. diameter or square rose-pot for most understocks. This is necessary for economic reasons to better utilize expensive greenhouse bench space and lower subsequent shipping costs.

After potting, the understocks are placed in a frame, bed, or bench, with 50% shade and grown until grafting time. Irrigation should be sufficient to induce moderate but not excessive growth. Fertilize only to encourage root regeneration but not excessive top growth.

Scions used for grafting must be selected with care. Current or past season's growth is selected depending on the season of grafting. Many nurseries maintain stock plants which are carefully pruned to yield healthy and sturdy terminal growth suitable for scions. The caliper or thickness of the scion should match that of the understock.

Commercial grafting is done in winter and summer, the former being the most common. Aside from requiring a heated greenhouse, winter grafting permits handling dormant scions and semi-dormant understocks. This materially reduces the risks involved in summer grafting.

In winter grafting most understocks are brought into a cool greenhouse sufficiently in advance of the actual grafting to permit initiation of new roots but *not* top growth. The scionwood is collected as close as possible to the actual time of grafting. It is necessary to collect scionwood before damage from harsh winter weather. They should not be cut when frozen.

Grafting is generally accomplished under comfortable working conditions at a work bench and with the grafter seated. This promotes a relaxed atmosphere which, in turn, permits a greater number of good grafts to be made. It also permits the grafters to steady their hands, if necessary, by resting elbows or forearms on the bench while cutting into the understock. Techniques vary considerably with different grafters. It is extremely important to make clean straight cuts, both on the understock and on the scion.

Two commonly used methods in pot grafting are the side and the veneer grafts. The understock is usually cut first, then the scion. This permits the grafter to keep the scion in hand after making the cut, thus preventing contamination that could occur if it were laid down on the bench. With the side graft a cut about 1¼ in. long is made from top to bottom on a straight portion of the understock, and as close to the soil as possible. The cut is shallow but through the bark and cambium and slightly into the wood. At the bottom of the first cut a second cut is made downward and inward about 3⁄16 to ¼ in. and through the veneer or flap made by it. This will leave a short projection or lip of bark and wood at the base of the cut on the understock to which the scion is fitted.

The scion is prepared by trimming off the foliage and branchlets on the lower quarter or third of the stem. A cut from top to bottom is made on the straightest side deep enough to expose the wood. The cut should be straight and level. A second cut is made across the base from top to bottom and slanting downward at the same angle as the cut lip on the understock. Lengthwise, the finished cut on the scion should match that on the understock. The scion is then fitted carefully to the understock being sure the respective cambium layers are in contact. If the scion thickness does not perfectly match that of the understock then the cambium layers of the two should be aligned along at least one edge. The two are then

tied making sure full and complete surface to surface contact occurs with no space between scion and stock. Rubber budding strips are the preferred wrapping material, but they must be removed prior to planting the finished graft in a bed or container.

The veneer graft is similar to the side graft; however, the second cut into the understock is not made, thus leaving a long lip or veneer. The scion receives three cuts instead of two, the first about 2 in. long on the straightest side, the second not quite as deep on the opposite side, and the third a short slanting cut across the bottom of the scion. The scion is then fitted to the understock with the slightly longer side of the scion fitted to the inner side of the understock. The veneer is then snugly fitted up and over the exposed outside cut of the scion and tied.

The grafts are then placed in a greenhouse bench with the pots plunged in moistened medium to a depth sufficient to cover the graft union. The medium may be sand, peat moss, perlite, or any combination. The purpose of burying the union is to keep the cut portions of stock and scion from drying out until callusing takes place. This time period will vary depending on the plant grafted and also the medium and ambient air temperatures. Initial medium temperatures should be kept in the range of 65° to 75°F for about 4 to 6 weeks. A heat source under the grafting bench (bottom heat) is highly desirable as it permits attainment of a proper medium temperature while maintaining lower top or ambient air temperature (50° to 60°F). After callusing has progressed to assure a "good take" the medium temperature should be lowered to approximately 55° to 65°F. The tops should be supplied with sufficient moisture to prevent cell collapse. This may be done by syringing, shading the greenhouse lightly, or by covering the grafts with white polyethylene sheeting. Daily lifting of the sheeting is recommended to introduce fresh clean air, thus preventing the buildup of pathogenic organisms.

After callusing is evident along the entire length of the union, the grafts are ready for hardening-off and preparation for subsequent transplanting. They are removed from the medium and carefully inspected for good callusing. Those that have taken well should at this time have the understock pruned back about half way. This serves to prepare the scion to assume its full responsibility as the top portion of the whole plant. It also reduces the total amount of foliage in the bench and serves to harden-off or prepare the callus tissue for transformation into bark. The pots of these good grafts are not plunged in the medium but placed on the surface of the medi-

um for another 4 to 6 weeks, after which time the remaining portion of the understock is removed. In this operation a clean sharp pruning shears is used, making a slanting cut of the understock down and away from the scion. Be careful not to cut the scion. Those grafts that have not callused sufficiently should be plunged again into the medium where they will remain until they do. Those grafts that have not taken and where the scion has deteriorated should be discarded.

SADDLE GRAFTING

LEONARD SAVELLA

Bald Hill Nurseries, Inc.
Victory Highway, R.R. #2, Box 140
Exeter, Rhode Island 02822

I will discuss a type of grafting, called a saddle graft, which is not used as often as some other types, but is valuable in certain situations. In saddle grafting the scionwood should be soft enough so that one can cut into the center of the wood with little effort and without splitting or otherwise damaging it. The scion is held with the base pointing away from the grafter. A 1 in. long cut is made starting about ¼ in. from the base and to the center of the scion. The scion is then turned over and an identical cut is made on the other side. The wedge of wood is removed. The rootstock is cut by making 1 in. long cuts on both sides of the top to form a wedge. The scion is placed tightly over the cuts on the rootstock and tied with a rubber band. If the union is to be waxed, grafting twine should first be used to tie the union.

The grafted plant is then placed in a poly chamber or grafting bench and buried with moist peat to above the union. Healing should be complete in 4 to 6 weeks. When the grafts are healed they are taken out of the chamber or bench, potted in growing medium, and set in the greenhouse where they are allowed to continue growing. In potting, the graft union should be left exposed.

Saddle grafting is more time consuming and, as a result, has decreased in popularity to the faster, more productive method of side veneer grafting.

Another technique I would like to discuss is the use of a poly bag chamber over the graft. The rootstock is decapitated at an angle at the desired height. Using the side veneer graft with the lip, the root is cut about 1¼ in. down. The scion is then cut on both sides into a wedge. Cutting the scion into a

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wedge shape will not leave a knob on the stem after the graft has healed and the plant has grown for a few years. Be sure the bark at the base of the scion does not separate from the wood. If it separates then make new cuts. Scions with the separated bark will not take. The union is then tied with a rubber grafting strip. It is advisable to leave a space between loops of the tie to allow for the callus to form between rootstock and scion. It is also advisable to keep the rubber strip above the base of the scion as it should not be covered.

After the graft is made and tied a ball of wet sphagnum moss, the size of a lemon, is tied to the rootstock 1 in. *below* the union. A plastic bag is then inflated and put over the scion and down below the sphagnum moss where it is tied with another rubber strip. This method is useful to the propagator who has limited greenhouse space. The grafted plants can be stood-up in the aisles of the greenhouse or at the ends where they are out of the way. No other care, except for watering, is needed until the grafts have healed.

SHIELD BUDDING

THOMAS L. MCCLOUD
Appalachian Nurseries
P.O. Box 87
Waynesboro, Pennsylvania 17268

Shield or "T" budding is the most widely practiced form of detached scion grafting used in commercial propagation because it is easy to perform, fast, and effective. It is used for hybrid roses, fruit trees, and ornamentals such as dogwoods, lilacs, and shade trees.

The knife used for budding is rounded on the end of the blade, which facilitates making the cuts. In contrast a grafting knife is straight to the end and comes to a sharp point. Budding knives may have a folding or stationary blade and usually some form of an attachment to help "lift" the bark if necessary after the cuts are made. This attachment can be a thin piece of bone attached to the handle or an extra "bump" on the top of the blade. Whatever knife is chosen, it should be of good quality, light-weight and "feel good" in the hand of the user. A budding knife should be kept razor sharp at all times. A budder must take the time to learn how to sharpen his knife properly. This will help to insure good clean cuts that heal properly.

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Budding is done in the field at the height of the growing season, usually during July or August. However, "T" budding can be done any time the bark is "slipping". At this time the bark will lift easily and be sappy or wet underneath.

Understocks used must be compatible with the scions to be budded. Understocks are started in the field from cuttings or seedlings 1 to 2 years before budding takes place. Pencil-sized (¼ in.) shoots are ideal for budding, although those up to 1-in. in diameter can be used. Only healthy, vigorous understocks should be selected. Two types of scions are used for budding, fresh and stored. Fresh scions or budwood are cut from mature current season's growth in July or August, just prior to their use. Leaves are removed, sometimes with the petiole remaining. Scions must be kept cool and moist to prevent drying out. They are most often wrapped in moist newspaper or burlap and placed in poly bags. Stored scions are cut in the fall from 1-year old mature growth. Leaves are completely stripped. They are then wrapped and placed in cold storage at 30° to 32°F until needed for budding, which can begin as early as May or June.

The vertical cut on the understock is made close to the ground and approximately 1 in. in length. The perpendicular or cross cut is made approximately ½ in. long and at the top of the vertical cut. Care must be taken to not cut too deeply especially with the cross cut.

To remove the bud the cut on the scion starts ½ in. below and cutting upward in one even stroke to ½ in. above. The bud can then be removed by a quick sharp cut or by pulling it off with a long "tail" of bark.

"Wooding" of the bud, that is removing the thin piece of wood from behind the bark, is sometimes performed before it is placed on the understock. Wooding of the buds will often help bud stands, particularly if the stock bark is not slipping well. Some budders insist on wooding; others say it makes no difference.

The bud is inserted under the bark of the understock by slipping it between the edges of the vertical cut, starting at the top and gently pushing the bud down. If the petiole is left attached to the scion, it can be used as a handle to push it into place. The bud can also be placed on the tip of the knife and pushed into the understock with the thumb. The tail or top of the bud shield is cut off flush at the top of the "T" cut. This ensures a snug fit and good cambial contact between the bud and understock.

Bud grafting is completed by tying or wrapping the inserted bud to hold the two components firmly together until heal-

ing is complete — about 2 to 3 weeks. Rubber strips, tape, raffia, buddling patches, or Parafilm can be used. With rubber strips, the tie is started below the bud and is secured by overlapping so *no open spaces* are showing around the cuts. The bud itself is not covered, with the tie being completed above the top of the perpendicular cut.

In conclusion, these main points should always be kept in mind when "T" or shield budding:

1. Make smooth clean cuts by using a sharp knife.
2. Strive for good cambium contact between bud and understock.
3. Exclude air from around the bud by using a snug, overlapping tie.

Thursday Morning, December 8, 1983

The Thursday morning session convened at 8:00 a.m. with Leonard Savella serving as moderator.

GIRDLING ROOTS, FACT OR FICTION

FRANCIS R. GOUIN
Department of Horticulture
University of Maryland
College Park, Maryland 20742

It has long been recognized that pot-bound plants are slow to establish after being transplanted. Unless their roots are disrupted from their circular habit of growth, the roots branch poorly and the plants often die from drought, despite being surrounded by moist soil. Close examination of pot-bound or near pot-bound plants that have been lifted, after having been in the ground for several months to several years, often reveals only a few roots originating from the bottom or from the top edge of the root balls. Generally, problems with transplanted container-grown plants occur within the first growing season. However, based on observations made in the Baltimore and Washington area over the past 5 years, it is becoming apparent that there could be long term problems with trees that originated in containers.

Approximately 10 to 20% of Norway maples (*Acer platanoides*) die as they approach 8 to 10 in. (20 to 25 cm) caliper from self-inflicted girdling roots. What causes these girdling roots to occur is unclear. However, in recent years there has been an increasing number of other tree species that have died

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Approximately 10 to 20% of Norway maples (*Acer platanoides*) die as they approach 8 to 10 in. (20 to 25 cm) caliper from self-inflicted girdling roots. What causes these girdling roots to occur is unclear. However, in recent years there has been an increasing number of other tree species that have died

as they approach similar caliper measurements. These include: red maple (*Acer rubrum*), pin oak (*Quercus palustris*), little leaf linden (*Tilia cordata*), Bradford pear (*Pyrus calleryana* 'Bradford') and flowering cherries (*Prunus subhirtella, P. yedoensis*). The trees that died or are dying had been growing normally in the landscape. In most instances a complete history on the trees is not available because the current owners were not present at the time the trees were transplanted. Since most owners are not willing to have stumps excavated for post-mortem examination, the probable cause of death can only be achieved through the process of elimination. Being able to excavate around the stump or lift the stump from the ground could help in identifying the cause of death.

Based on a very limited number of observations of shade trees affected, girdling roots were found to be the most probable cause of death or decline. After watching this tree death occur, there are several characteristic symptoms that may help indicate possible girdling root problems. Early symptoms include: a gradual shortening of terminal growth over the years despite good growing conditions; small size leaves and sparce looking foliage; lopsided top growth; premature fall coloration of certain branches, primarily in the middle or on one side of the tree; some wilting and dropping of summer green foliage, especially during drought periods; and die-back of branches in sections of the canopy. Death from girdling roots is gradual and may occur over a period of 3 to 5 years.

Evidence of possible root girdling may also be seen by inspecting the trunk of trees near the ground. The trunk of a normal tree is flared uniformly around the base. A tree that is being affected by girdling roots may have one or more flat sides, like a telephone pole, where the trunk enters the ground (Figure 1). This is an indication that girdling roots have prevented normal development of surface roots. However, flaring at the base of the tree trunk is not always assurance that girdling roots do not exist. There have been several instances where callus tissue has formed over the girdling roots giving the appearance that the tree trunks were normal (Figure 2).

If the symptoms are recognized early, it appears that the problem can be corrected by cutting out the girdling root(s) with a mallet and wood chisel. Recovery is slow but surgery does seem to work. However, in most instances, nothing is done until the tree dies. Since post-mortem examinations are not required, the cause of death is often attributed to common diseases or infestation by insects discovered at the time of inspection, or toxic levels of natural gas from leaking underground service lines.

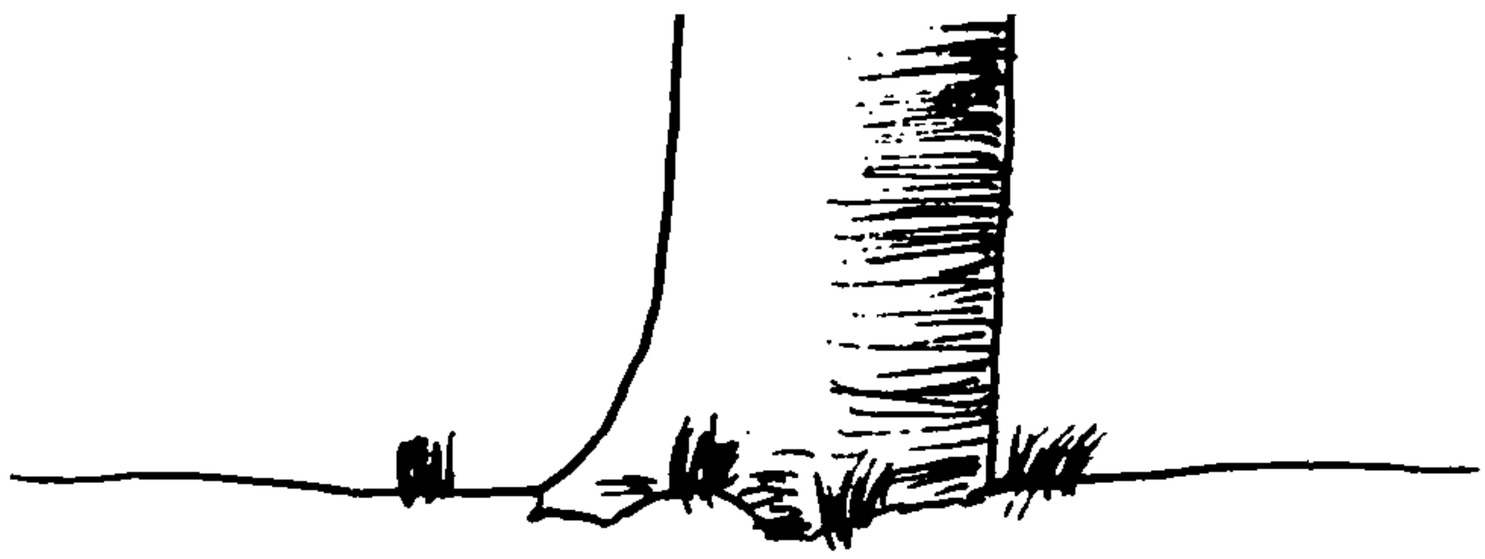

Figure 1. Flat side of tree trunk indicates a possible girdling root located just beneath soil surface. Girdling roots frequently prevent surface roots from developing normally.

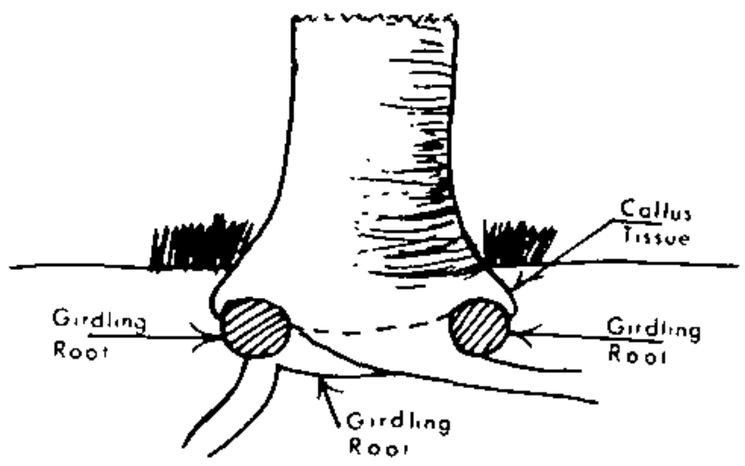

Figure 2. Although the tree trunk appears normally flared, swelling at the base is due to callus tissue forming over the girdling roots.

Container culture of ornamental plants is likely to continue because of its many advantages. However, it is widely acknowledged that plants that are allowed to remain in containers too long become pot-bound. A plant becomes pot-bound when the roots have completely permeated the medium and are growing in a circular pattern forming a near solid mat along the inside walls of the container. Forcing the roots to grow in a circular pattern also occurs when bare-root field-grown plants are jammed into containers or small planting holes. This practice is becoming more common as nurseries expand and winter activities are created. Winter-potting or peat-balling of fall-dug fruit or shade trees without first pruning the roots may have similar effects in encouraging the formation of girdling roots. These plants could become as much of a problem as container-grown plants.

It may not be necessary for container-grown plants or potted field-grown plants to become pot-bound for girdling roots to form. It appears as if once the roots at the top of the root ball develop their circular habit of growth, there exists a potential problem.

Measurements taken of girdling roots uncovered from dead or dying trees appear to indicate that the trees may have

been grown in 6 in. (15 cm) or 8 in. (20 cm) containers. It has long been a recommended horticultural practice to disturb the roots of plants that have been grown in containers when transplanting. This practice is often ignored for fear that disturbing the roots will cause harm to the plant and may even be deterimental. The present recommended horticultural practice of "Butterflying" the rootball (Figure 3) only disrupts the roots at the bottom half of the root-ball. This practice not only stimulates more rapid branching of roots but may also prevent root-rot diseases from becoming established in roots that otherwise would have been planted too deep. Although the practice of "Butterflying" root balls of container-grown plants at planting time has been widely accepted by landscape contractors, it does not help solve the girdling root problem. Cutting and disturbing the roots at the bottom of the root ball does nothing to disrupt the circling roots in the upper half of the root ball.

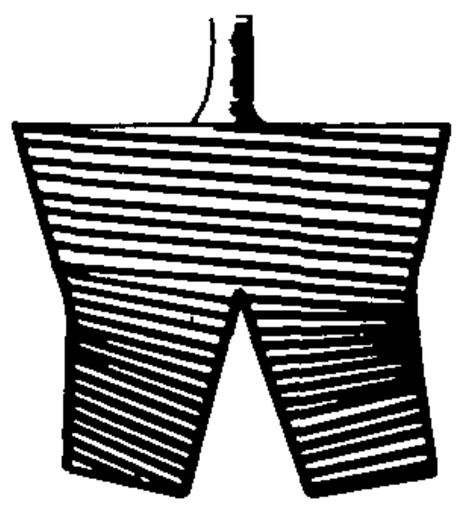

Figure 3. "Butterflying" the rootball only disturbs the roots at the bottom half. It does not destroy the circling roots in the top-half of the rootball that are potential girdling roots.

Current studies indicate that making 4 or more cuts approximately 1 in. deep (2.5 cm) uniformly spaced the length of the root ball at the time of transplanting may be sufficient to solve the problem. The cuts can be made with a sharp knife or the point of a digging spade. Cutting the roots in this fashion does not appear to adversely affect the top growth but stimulates the roots to branch at the cut ends.

Another method of preventing girdling roots from forming is by growing the plants in round containers with protruding ribs, or in square containers. Either type of container will force the roots to grow downward as they touch the inside walls of the container. However, experience has already demonstrated that unless the bottoms of these root balls are "Butterflied" at the time of transplanting, the root system is likely to retain the shape of the container even after having been transplanted for several years.

Regardless of which container is used, it is apparent that an educational program is essential. Propagating containers used for direct sticking should either be square-sided or, if

round, engineered with ribs protruding into the propagating medium to prevent the roots from developing a circular habit of growth. When transplanting seedlings or rooted cuttings into containers, nurserymen should select similar containers in order to avoid root girdling problems in the future.

Educational programs are necessary to teach nurserymen, landscape contractors, and home gardeners the art of transplanting container-grown or potted and peat-balled field-grown plants to promote rapid establishment and to avoid girdling root problems.

RON GIROUARD: I would like to make several recommendations to tie in with what you have said: 1) Use appropriate containers with ridges to direct the roots in the right directions. 2) When you pot up your rooted cuttings don't wait until the roots are 6 in. long.

ART VANDERKRUK: How deep did you make the vertical cuts?

FRANK GOUIN: About one inch because it is the outer roots that are circling.

TED MEYERS: Just a comment. We have used a square 2-in. milk carton type tube and find that it does a good job of directing roots down. We find, however, that the vertical column of roots remains intact and I am not sure that directing the roots down is the total answer.

FRANK GOUIN: We have found with the citrus tube, that if you split the bottom of the root ball and bring the roots up, you get much better survival.

BILL SCHWARTZ: I have been using a one gallon container that has ridges every inch instead of creases. The bottom of the pot is dome shaped and this forces the roots back up. When you cut the bottom roots, root proliferation occurs from everywhere.

LEN SAVELLA: When you cut these roots do you find any diseases developing?

FRANK GOUIN: No.

PROMOTION OF ROOT REGENERATION IN DIFFICULT-TO-TRANSPLANT SPECIES[1]

D. K. STRUVE[2], R. D. KELLY[3], AND B. C. MOSER[4]

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Difficult-to-transplant species such as scarlet oak, *Quercus coccinea*, and black gum, *Nyssa sylvatica*, have considerable ornamental value, but are not widely offered in the nursery trade. Poor transplant survival has made these species uneconomical for nurserymen to produce and landscapers to install. If a means of increasing transplant survival can be found then these and other ornamentally valuable but difficult-to-transplant species could be added to the nursery catalog lists and increase the range of plants available to landscape architects.

It has been estimated that as little as 2% of the soil volume originally exploited by a plant's root system is retained in standard balling and burlapping operations (20). Root systems are further disturbed when a plant is dug bareroot. Without the protective soil ball the roots, especially the small feeder roots most responsible for water and nutrient absorption, are easily desiccated and broken. It is essential that a plant rapidly regenerate a root system to insure survival following transplanting.

Natural Pattern of Root Regeneration. Ease of transplanting is directly related to the density of the root system and the rate of root regeneration. Pirone (12) has listed plants based on their relative ease of transplanting. Those rated as difficult-to-transplant are typified by a coarse root system. Characterization of twice-transplanted 1.5-in. caliper scarlet oak (considered difficult-to-twice-transplant) root systems found that they were less fibrous than the more easily transplanted pin oak (17). Also, the rate of root regeneration was slower in scarlet oak seedlings than in pin oak. In spring, scarlet oak regenerated fewer roots, 6 vs. 16, and began root regeneration 4 weeks later than pin oak when grown under greenhouse conditions.

[1] This research was funded in part by a grant from the Horticulture Research Institute.
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The dynamics of honeylocust root regeneration should be studied and contrasted with those of scarlet oak since the former is considered easy-to-transplant but coarse-rooted. The difference in transplant ability might be attributed to rate of root regeneration and/or rate of root elongation.

The potential for root regeneration varies with species, the physiological and developmental stage of the plant, and the environmental conditions during root regeneration. Generally, under field conditions there are two peaks in the natural pattern of root regeneration (16). The fall peak results almost exclusively from the elongation of existing roots, whereas the spring peak results from both the elongation of existing roots and the initiation and subsequent elongation of newly initiated roots. Tulip tree (4) and black walnut (19) seedlings exhibit the typical seasonal pattern of root regeneration. Indolebutyric acid (IBA) applications to the root systems at transplanting only enhanced spring root regeneration, having little effect in the fall. Root regeneration resulted exclusively from elongation of newly initiated roots, as the seedlings used in these studies had no intact roots. The root tips were either lost during digging or were pruned before auxin treatment.

When a coarse-rooted species is dug few intact roots are retained. Therefore, root regeneration usually results from new root initiation and subsequent elongation. Root initiation occurs primarily in the spring in the presence of nondormant buds and is often inhibited by dormant buds (1, 14). The natural bud dormancy developed in the fall is broken by exposure to chilling temperatures during winter and early spring. Because harvesting leaves coarse-rooted species with few intact roots, root regeneration (via new root initiation and elongation) would not occur until spring. Thus, the common practice of transplanting difficult-to-transplant species in spring has a physiological basis.

Increasing Root System Density and Improving Root Regeneration in Difficult-to-Transplant Species. Difficult-to-transplant species commonly have a well-developed taproot. Although the taproot is damaged by repeated digging and root pruning during production, the root system remains coarsly branched. Nurseries, in an effort to improve on the plant's root regeneration characteristics, have explored several means of increasing the density of the root system. Among these methods is container production. By growing seedlings in open bottom containers, the taproot is air-pruned as it grows beyond the bottom of the container. This method has increased the fibrousness of the root system but concentrates the actively growing roots at the container bottom. If a 9 in. deep container

is used, all of the seedling's actively growing roots will be 9 in. below the soil surface when planted (5). Most nutrients are located in the upper 3 to 4 in. of soil. In reforestation work this concentrating of roots has caused stunting, presumedly due to poor nutrition. In nursery practice, stunting due to poor nutrition probably would not be a problem since adequate nutrition is usually provided by the grower. However, there is the problem of little or no root distribution in the top 9 in. of soil, necessitating a deeper soil ball when harvesting.

Treating root systems of difficult-to-transplant species with auxin to increase root regeneration is an alternative to container production and a proven method of increasing transplanting success (Table 1). However, as mentioned earlier, auxin application is most beneficial in stimulating root regeneration in the spring.

The root soak or dip method, simply soaking or dipping the root system in an auxin solution, would seem to be the commercially acceptable method due to ease of application. This method does require large volumes of auxin solution to adequately treat root systems of all but small seedlings.

Treating black walnut (19), tulip tree (4), and scarlet oak (18) with IBA root soaks increased root regeneration by increasing the number of roots regenerated. The optimum concentration for a 5 min. soak ranged from 1,000 to 3,000 ppm. Concentration above 3,000 ppm or soaks longer than 5 min. inhibited root regeneration and shoot development.

Table 1. Species, method of auxin application, and auxin concentration used to stimulate root regeneration in seedlings.

Species	Method of Application	Auxin	Concentration (ppm)	Reference
Acer saccharinum	Lanolin paste	IAA,IBA	1000, 3000	13
Cercis canadensis	Soak	IBA	3000	11
Crataegus phaenopyrum	Toothpick, soak	IBA	1000, 3000	z
Carya illinoinensis	Toothpick, soak & others	IBA	400, 1000	2, 15
Juglans nigra	Soak, toothpick	IBA	1000, 3000	11, 19
Liriodendron tulipifera	Soak	IBA	1000, 3000	4
Nyssa sylvatica	Soak	IBA	1000, 3000	11
Pyrus communis 'Bartlett'	Toothpick, talc	IBA	1000, 8000	8
Quercus alba	Soak	IBA	1000, 3000	11
Q. borealis	Soak, toothpick	IBA	100, 300, 1000, 3000	6,z
Q. coccinea	Soak, toothpick	IBA,NAA	100, 300, 1000	18
		2,4-D 2,4,5-TP	3,000, 10, 100, 300	
Q. palustris	Toothpick	IBA	1,000 10,000	9
Tilia × *euchlora*	Toothpick	IBA	1000	2

[z] Struve, unpublished data.

Other auxins have been tested; naphthaleneacetic acid, 2,4-dichlorophenoxyacetic acid and 2,4,5-trichlorophenoxyacetic acid, but the results were varied and require additional research.

Inserting auxin impregnated toothpicks transversely through a root is another means of stimulating root regeneration (2, 8, 9, 11, 15, 18). This method was first used by Romberg and Smith (15) on pecan and has been used subsequently on a number of species (Table 1). Auxin impregnation is accomplished by placing toothpicks in an auxin solution and drawing a vacuum or by allowing them to soak overnight.

The auxin-impregnated toothpick method has several advantages: First, it increases the number of roots regenerated. With one-year-old scarlet oak seedlings 19 times more roots were regenerated by toothpick-treated seedlings than by control seedlings and 3 times more roots than the best auxin root-soak treatment, 19, 1, and 5 roots, respectively (18). Second, the majority of the newly regenerated roots arise from the site of toothpick insertion. With natural root regeneration or auxin soaks the majority of the roots are regenerated near the cut surface. When roots are regenerated near the cut surface, most of the benefit of increased numbers of regenerated roots is lost in the subsequent harvest operations. Toothpicks, however, can be inserted near the crown of a seedling, resulting in less root loss during digging. The toothpick treatment allows nurserymen to engineer a plant's root system. The toothpick could be inserted into the root at the time plants are graded.

One criticism of the toothpick treatment could be the cost. Moser (10) has estimated the cost of auxin impregnation and toothpick insertion to be 1.3 cents each. A small study was begun in 1982 to determine if the benefits of toothpick treatment would justify the cost.

The field study was begun, with the cooperation of Manbeck's Nursery, New Knoxville, Ohio, by treating the root systems of ten 8-ft red oak liners with 5 auxin-impregnated toothpicks per plant in March, 1982. The trees were labeled and field-planted that spring with untreated control trees. One treated tree died following transplanting. Three trees were dug bare root in November, 1982, to examine root regeneration. Caliper and height of the remaining 6 treated and 10 adjacent untreated trees were measured in October, 1983. Toothpick-treated red oak liners averaged 4 ft. (1.3 meters) taller and 0.4 in. (1.1 cm) greater caliper than untreated liners (Table 2).

Table 2. Height and caliper of toothpick-treated and control red oak liners 19 months (two growing seasons) after treatment. Eight-foot tall liners were treated March, 1982, and measured October, 1983.

Treatment	Height (m)	Caliper (cm)
Control[z]	4.0 (12 ft)	3 ± 0.76 (1.25 in)
Toothpick[y]	5.3 (16 ft)	4.1 ± 0.5 (≃ 1.75 in)

[z] Average of 10 trees.
[y] Average of 6 trees.

The 1983 Lake County Nursery Exchange catalog lists 1¼, 1½, and 1¾ in caliper bare-root red oaks at $21.00, $26.65 and $33.85, respectively. The toothpick-treatment trees average ¼ to ½ in larger caliper than untreated trees, returning between $5.65 and $12.85 (the difference in list price between 1¼ and 1½ and 1¾ in caliper trees) for the 6.5 cent treatment cost.

An additional benefit of any auxin treatment, especially the toothpick treatment, is increased survival following transplanting. The toothpick treatment decreased mortality of red oak seedlings from 25% to 4%, 43 vs. 5 of 125 seedlings, respectively (Struve, unpublished data).

Auxin treatments, via root soaks or impregnated toothpicks, in addition to promoting root regeneration, have consistently promoted shoot growth the first year following treatment (2,4,6,8,9,19). It is not known how long shoot growth is promoted.

Stimulation of Root Regeneration in Easy-to-Transplant Species. The toothpick method has been used to stimulate root regeneration in 3 to 7½ in caliper pin oaks transplanted bareroot (9 and Struve, unpublished data). In the first experiment, transplant survival and growth of pin oaks transplanted via tree spade, bareroot or bareroot but treated with auxin-impregnated toothpicks, were compared. Although shoot growth was not as great as tree spade dug trees, the toothpick-treated bareroot trees had greater shoot growth than untreated bareroot trees. Survival for all 3 treatments, a total of 41 trees, was 100%. The toothpick method is the best means of auxin treatment for large sized trees. The amount of auxin solution needed to treat the root system of a 3 in caliper or larger tree would be prohibitive.

Auxin treatments, via root soaks or impregnated toothpicks, are effective means of increasing transplant survival, increasing root system density, and increasing shoot growth. However, there are many unanswered questions pertaining to the number of roots regenerated, the longevity of the regenerated roots, and the relationship between root system density, increased shoot growth, and transplant survival. Additional

research is needed to answer these and other practical questions in order to improve the survival of plants moved bare-root.

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RICK RAY: How do you put the toothpicks into the roots?

DAN STRUVE: It depends on if you have electricity or not. We have done such crass things as driving a nail into the root and pulling it out and then inserting the toothpick. Ideally you should have an electric drill.

RICK RAY: Could you use a system like they use in the army for injecting?

DAN STRUVE: It is possible.

CAMERON SMITH: Have you done any direct injection experiments?

DAN STRUVE: No.

CAMERON SMITH: With a little DMSO you might be able to mobilize the auxin.

HERBICIDES FOR CONIFER SEEDBEDS

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Weeds are the most costly pest to control during the production of conifer seedlings. Competition from weeds causes losses in density and quality. Hand-pulling weeds is expensive and also causes a decrease in density when conifer seedlings are pulled along with the weeds. For these reasons, a safe and effective form of chemical weed control is needed.

Weed Control Program. When planning production schedules, growers should include a weed control program. In the past, weed control was often treated like firefighting — the problem was attacked after it was started. But you can have much safer and effective weed control by developing a weed control program. A program incudes three basic steps:

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Step 1. Eliminate all weeds prior to planting. It is especially important to kill all perennial weeds because they are not controlled by preemergence herbicides, which are generally the safest.

Step 2. Prevent weed growth. There are now several preemergence herbicides labelled for use in conifer seedbeds. Repeat applications may be necessary for season-long control.

Step 3. Eliminate weeds when they appear. There will always be some weeds that escape your preventive measures. Destroy them before they get too well established and difficult to control.

Eliminating Weeds Prior to Planting. Fumigation has been the standard practice used to eliminate weeds prior to planting. The disadvantages of fumigation are its high cost and its destruction of beneficial soil microorganisms, including mycorrhizae-forming fungi.

Nursery seedbeds do not have to be refumigated every time a new crop is sown. When the beds are not going to be fumigated, Roundup (glyphosate) can be applied before planting to eliminate weeds. For beds to be sown in the fall Roundup can be applied 7 to 10 days before bed preparation. For beds to be sown in the spring the Roundup should be applied in the preceding September. Spring applications are not recommended because many weeds are at too early a developmental stage to be adequately controlled by Roundup.

Roundup is a nonselective, systemic herbicide that is absorbed through the foliage and translocated to all palnt parts. Since it kills below-ground plant parts, it effectively controls perennial weeds. For best results, Roundup should be applied to actively growing well-developed weeds. Do not mow or cultivate before applying Roundup. Mowing reduces the leaf area capable of absorbing the chemical, and cultivation breaks up the weed roots and spreads the pieces deeper and over a wider area. Each piece is capable of forming a new plant. These pieces do not all start growing at the same time and it is very difficult to kill all of them.

Roundup should not be applied when rainfall is predicted within the next 24 hours. It is best to allow 24 hours for absorption by the plant, but some control can be obtained if there is 6 hours between application and rainfall. Roundup requires 3 to 10 days to move throughout a plant, depending on weed species and growing conditions. The better the growing conditions, the faster it will be absorbed and translocated. Though the weed is doomed as soon as a sufficient amount of Roundup has translocated to its roots, injury symptoms may

not appear for 2 weeks or more. You do not have to wait until the weeds are dead to work the soil. Generally, a 3 to 5 day waiting period after application is sufficient.

Roundup is inactivated rapidly in the soil so it can be safely used just prior to planting.

Preventing Weed Growth. There are 5 herbicides available that can be used to prevent weed growth in conifer seedbeds. Three of them are labelled for use at the time of planting.

Enide (diphenamid) has been labelled for use on conifer seedbeds for a number of years. It should be applied one day prior to seeding or within one month after seeding. It has not been widely used because of its limited spectrum of control and its short residual. It primarily controls grasses but for only 4 to 6 weeks. Reapplications can be made at 6 week intervals, but this practice gets expensive and is of limited value if broadleaved weeds are present.

Modown (bifenox) is labelled for use on conifer seedbeds only in the southern and western United States. It should be applied to seedbeds within 48 hr of sowing the seed. It controls broadleaved weeds for about 8 weeks at recommended rates, but is weak on grasses. The label warns that it may reduce the survival of Douglas fir, though I have not seen this problem in studies I have conducted.

Goal (oxyfluorfen) should be applied after seeding and mulching, but prior to conifer seed germination. It provides excellent control of broadleaved weeds and very good control of grasses. The recommended rate of application extends from 0.25 to 1 lb active ingredient per acre (AIA). Colorado spruce has limited tolerance to Goal, so you should not apply more than 0.5 lb AIA on seedbeds of Colorado blue spruce. Depending on the rate of application, Goal will control weeds for 8 to 16 weeks.

Ronstar and Scott's Pro-Gro Ornamental Herbicide I (Scotts OH-I) are different formulations of the same chemical — oxadiazon. Ronstar contains 2% active ingredient and Scott's OH-I, 4%. Ronstar, or OH-I, should not be applied until 5 weeks after emergence of the conifer seedlings. Both provide excllent control of broadleaved weeds and very good control of grasses for 8 to 12 weeks.

Modown, Goal, and Ronstar/Scott's OH-I are all in the same class of herbicides — they kill weeds on contact. Their preemergence activity is based on the fact that they have a low solubility in water and they form a chemical barrier on the soil surface. Weed seedlings are burned off at the soil line as they emerge through the barrier.

Devrinol (napropamide) is the last of the preemergence herbicides that is labelled for use in conifer seedbeds. It is an inhibitor of root growth and may cause injury to the conifers if applied during the first growing season. Because it can be lost to photodecomposition and volatilization in warm weather, it should be applied in cool weather (less than 45°F). It can be applied in warm weather if application is immediately followed by 0.5 to 1 in. of irrigation water. Devrinol can be applied in the fall following the first growing season. It has a low solubility in water so it will be active the following spring and summer. Devrinol provides long-term control of grasses, but is weak on broadleaved weeds.

Eliminating Weeds in Plantings. There are also 5 herbicides available that can be used to eliminate weeds that escape the preventive measures. Goal and Modown, in addition to their preemergence activity, provide limited postemergence control of weeds. They will kill broadleaved weeds less than 4 in in height or diameter, and most grasses less than 3 in tall. Larger weeds will be burned, but their growing points will not be killed. Ronstar/Scott's OH-I is in the same herbicide class as Goal and Modown, but it does not have postemergence activity because it is only available in the granular formulation.

Goal provides better postemergence control of weeds than Modown, but it is also more likely to injure the conifers if improperly applied. Neither should be applied less than 5 weeks after emergence of the conifer seedlings because of the probability of injury to the primary needles and growing point. During this time weeds can grow past the stage at which they can be controlled, so the value of a preemergence application is evident.

Though the primary needles and growing point are sensitive to postemergence applications of Modown and Goal, secondary growth apparently is not. A number of studies, including a range of application rates, have shown that these herbicides can be safely used 5 or more weeks after conifer seedling emergence.

If the weeds are at least 4 in. taller than the conifer seedlings, a wick applicator can be used to apply Roundup. Depending on the weed species present, use either a 10 or 20% solution of Roundup. Carefully control the flow rate to the wick to avoid dripping herbicide solution on the conifers.

Two new herbicides that have just been cleared for use on ornamentals this year are Fusilade (fluazifop-butyl) and Poast (sethoxydim). Both provide postemergence control of almost all

annual and perennial grasses. They do not provide any broad-leaved weed control or any preemergence control of grasses.

Fusilade and Poast are both rapidly absorbed by the foliage of the plant. Within an hour of application, the majority of the chemicals have been absorbed. This reduces the chance that rainfall will decrease the effectiveness of a treatment.

After absorption, the chemicals are rapidly translocated to both the above- and below-ground growing points, where they cause all growth to stop. The first symptoms of injury are termination of growth and death and decay of the inner whorl of the grass plant. At this time the outer leaves may appear green and healthy, but it is only a matter of time before they die. The application rate, plant species and size, and environmental conditions determine whether or not the underground parts of perennial grasses will be completely killed.

Under good growing conditions (good soil moisture, high temperature, and high humidity), the initial symptoms will appear in 5 to 7 days. It may take 2 to 3 weeks for the grass to wilt and die, so be patient.

The growth stage of the grass at the time of application is not critical. It is important that it be actively growing. Annual grasses 2 to 6 in tall are easily controlled with one application at 0.1 lb AIA. Grasses up to 18 in can be controlled, but the application techniques must be adjusted to assure complete coverage of the weeds. Raise the nozzles and increase the rate of application, spray pressure, and volume applied per acre. To obtain optimum control use a non-ionic surfactant at the rate of one quart per acre of 1% v/v.

The cost per gallon of Fusilade and Poast is high, but because low rates of application (0.1 to 0.5 lb AIA) provide excellent grass control, their cost per treated acre is reasonable.

RECOMMENDATIONS

All weeds should be eliminated prior to planting by fumigating the soil or by applying Roundup at 2 to 3 lbs AIA.

Goal is the best preemergence herbicide to use at the time of planting because it provides safe, broad spectrum, long lasting control. Use 0.5 lb AIA on spruces and 0.75 lb AIA on all other labelled species. For continued preemergence control follow these guidelines:

1. *Summer* — If needed, apply Goal at 0.25 to 0.5 lb AIA or Ronstar/Scott's OH-I at 2 lb AIA no sooner than five weeks after conifer emergence.

2. *Fall* — Apply Devrinol at 2 to 3 lb AIA in late fall, but before the ground freezes. This will provide preemergence grass control into the following summer.

3. *Following spring* — Apply Goal at 0.75 lb AIA in the spring prior to budbreak, or Ronstar/Scott's OH-I at 2 lb AIA anytime in the spring before weed emergence.

To eliminate grasses that escape the preventive measures apply Fusilade or Poast at 0.25 lb AIA plus a non-ionic surfactant. If perennial grasses regrow, reapply at the same rate. Small broadleaved weeds and some grasses can be controlled with an application of Goal at 0.25 to 0.5 lb AIA. Do not apply sooner than 5 weeks after conifer emergence. Goal can be reapplied in 6 weeks if needed. A 10 to 20% solution of Roundup can be wick-applied to control large or especially troublesome weeds.

Table 1. Conifers listed on herbicide labels.

Trade Name	Common chemical name	Formulation	Conifers listed on the label
Devrinol	napropamide	2G,5G,50WP	Douglas fir, fir, hemlock, Japanese larch, juniper, pine, spruce, *Taxus*
Enide	diphenamid	50WP,90WP	fir, hemlock, larch, pine, at the time seeding; spruce after seedlings are one month old
Fusilade	fluazifop-butyl	4EC	arborvitae, Douglas fir, fir, hemlock, pine, spruce, *Taxus* (delay applications until after initial hardening)
Goal	oxyfluorfen	1.6EC	Colorado blue spruce, Douglas fir, pine (loblolly, slash, longleaf, shortleaf, eastern white, Virginia, ponderosa, lodgepole)
Modown	bifenox	4F	southern United States — pine (loblolly, longleaf, shortleaf, slash, eastern white) western United States — Colorado spruce, Douglas fir, redwood, western hemlock, fir (California red, grand, noble, white), pine (Monterey, ponderosa, sugar)
Poast	sethoxydim	1.5EC	Fraser fir, pine (eastern white, loblolly, mugho, Virginia), spruce (Norway, white)
Ronstar/ Scott's OH-I	oxadiazon	2G 4G	pine (loblolly, slash, eastern white)

PRE- AND POST-PLANT EMERGENCE HERBICIDES AS THEY AFFECT SEED GERMINATION AND GROWTH OF FOUR HARDWOOD AND ONE CONIFEROUS SPECIES GROWING ON SEWAGE SLUDGE COMPOST-AMENDED SOIL[1]

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Abstract. Weed control tests were conducted in seedbeds amended with composted sewage sludge and seeded to 4 hardwood and 1 coniferous species, at a forest tree nursery using 4 preemergence herbicides applied soon after seeding and granular soil fumigant as a preplant soil treatment. Napropamide and bifenox applied in combination at 1.7 and 3.4 kg/ha provided good weed control without reducing populations and growth of *Quercus rubra*, *Juglans nigra*, and *Pinus taeda* but caused a severe reduction in the population and growth of *Cornus florida* and *Liriodendron tulipifera*. Oxyfluorfen at 0.3 and 0.6 kg/ha provided acceptable weed control without causing any decline in population or growth in any of the species tested except *L. tulipifera*. Prometryn did not provide acceptable weed control at either 0.7 or 1.4 kg/ha. Weed control with sodium azide as a preplant soil treatment at 400 kg/ha was unacceptable.

Although several herbicides are labeled for use on conifer seedbeds (1), none are currently labeled for similar use on seedbeds of hardwood species. Bing (3) reported post-plant premergence treatment with oxyfluorfen at 1 to 9 kg/ha and napropamide at 2 to 18 kg/ha was suitable for use on dogwood liners. Ahrens, *et al.* (2) reported that trifluralin at 2 kg/ha, oxyzalin at 1 kg/ha or DCPA at 6.7 kg/ha did not injure dogwoods when applied as the seedlings emerged.

The purpose of this study was to screen available herbicides known to control weed species, indigenous to the nursery, that could be applied, either preplant or immediately after seeding, that would not affect the germination and growth of 4 commonly grown hardwood species and 1 conifer species.

MATERIALS AND METHODS

These studies were conducted at the Buckingham Forest Tree Nursery in Harmans, Maryland on Gaylestown sandy loam. Within one month of seeding the soil was amended with 124 dry t/ha (48t/ha) of screened compost (through a 2 cm

[1] This research was supported in part by a cooperative agreement with the Biological Waste Management and Organic Resource Laboratory, U.S.D.A. and A.R.S., Beltsville, MD and with the assistance of the Maryland Forest, Park and Wildlife Service, Department of Natural Resources, Annapolis, MD.
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screen) made from lime-dewatered sewage sludge (Blue Plains, waste water treatment facilities) and woodchips, composted using the aerated pile method (4) by Maryland Environmental Services, Annapolis, Maryland. The compost was rototilled to a depth of 25 cm 3 weeks before seeding. Plots 3 m long and 15.2 m wide were randomly arranged in 3 continuous replications in the compost-treated area. Two weeks before seeding, sodium azide 15G (PPG Industries, Inc. Pittsburgh, PA 15222) was applied to one plot in each replication (soil temperature 20°C and at nearly field capacity) using a Gandy Turf Tender, rototilled to a depth of 15 cm and covered with 4 mil clear copolymer for 1 week. The plots were allowed to air-out for one week and the area was dragged smooth in preparation for seeding.

Just prior to seeding on November 18, 1981, beds 1.5 m wide and 91 m long with 30 cm wide isles were marked using tractor tire tracks. In the bed to be seeded with *Juglans nigra*, 6 V-shaped grooves 6 cm deep and 6 cm wide and 25 cm apart were made using a modified drag. Seeds for all 4 species of hardwoods were uniformly sown by hand in each plot and covered with a 1:1 mixture of sand and sawdust to a depth of 1 cm. Seeds of *Pinus taeda* were drilled on December 18 using a Whitefield Nursery 8 row Seeder (R.A. Whitfield Co., Mableton, GA 30059).

Within a day after each seeding period, the following preemergence herbicides were applied: prometryn (Caparol 80W, CIBA-GEIGY Corp. Greensboro, NC 27419), oxyfluorfen (Goal 2E, Rohm and Haas Co., Philadelphia, PA 19105) napropamide (Devrinol 50 WP and Devrinol 10G, Stauffer Chemicals, Westport, CT 06881) and bifenox (Modown 80WP, Mobil Chemicals, Richmond, VA 23261) were applied alone or in combination. The granular herbicide was applied using a manually operated Casoron applicator; sprayable materials were applied using a hand-held boom with 0.0108 T-jet nozzles at 276 kPa (40psi) powered by compressed CO_2. An untreated plot in each replication served as a control. On December 20, all beds were mulched with straw held in place with chicken wire.

In mid-April, 1982, the straw was removed. On April 29 and again on June 9, the predominant weeds in each plot were identified and degree of weed control evaluated as 1 = high weed population, and 10 = no weeds present. The beds were handweeded after each evaluation and, when necessary thereafter, during the remaining growing season and irrigated as necessary. In March, 1983, the seedbeds were root-pruned and a 2 meter long bed section from the center of each plot from each species was hand-pulled. The seedlings were counted

and graded according to stem length measured from the root collar to the terminal bud. Measurements were taken in increments of 10 cm; e.g.: 1-10, 11-20, 21-30, etc. The total number of seedlings harvested, as well as the mean stem length of each speices per plot, were statistically analyzed.

RESULTS

Weed Control. Weed growth during the April 29 observation period was low and there was little noticeable difference between the control and the treated plots (Table 1). Dominant weed species during this observation period included: *Poa annual* (annual bluegrass), *Eupatorium capillifolium* (fennel), *Stellaria media* (chickweed), and *Allium vineale* (wild garlic). However, by the June 9 observation period, weed growth in the control plots was extensive. The dominant weed species observed included: *Rumex* sp. (dock), *Ambrosia artemisiifolia* (ragweed), *Linaria genistifolia* ssp. *dalmatica* (toadflax), *Digitaria* sp. (crabgrass), *Mollugo* sp. (carpetweed), *Portulaca oleracea* (purslane), fennel, *Polygonum pensylvanicum* (smartweed), *Rumex acetosella* (red sorrel) and *Erigeron canadensis* (horseweed). The best weed control was observed in plots treated with granular or wettable powder napropamide and bifenox combination at all concentrations. Plots treated with oxyfluorfen provided acceptable weed control at either concentration while weed control in plots treated with sodium azide was unacceptable. The high level of prometryn gave slightly better weed control than the lower level.

Table 1. Degree of weed control from visual evaluation made before and after seed germination of tree species.

Herbicide	kg,a.i./ha	Rating[1] April 29, 1982	Rating[1] June 9, 1982
Control	—	9.7	1.7
Sodium azide G	400	9.3	4.3
Oxyfluorfen	0.3	9.0	7.0
Oxyfluorfen E.C.	0.6	8.5	7.3
Prometryn W.P.	0.7	9.7	3.3
Bifenox W.P.	3.4		
Napropamide W.P. and	3.4	9.0	9.0
Bifenox W.P.	6.8		
Napropamide G. and	1.7	9.5	8.7
Bifenox W.P.	3.4		
Napropamide G. and	3.4	8.8	9.7
Bifenox W.P.	6.8		

[1] 10 = no weeds, 1 = high weed population

Tree Species Response:

Quercus rubra and *Juglans nigra*. None of the herbicides tested appeared to have reduced the population or top growth of either *Q. rubra* or *J. nigra* when compared to the control. (Tables 2 and 3)

Liriodendron tulipifera. Only *L. tulipifera* growing in plots treated with prometryn and sodium azide were similar in population and mean stem length as those growing in the control. Populations of *L. tulipifera* growing in plots treated with oxyfluorfen or in combinations of napropamide and bifenox were significantly reduced. However, the herbicides did not appear to affect the stem lengths of plants that survived.

Cornus florida. Herbicide response on *C. florida* seedbeds were highly variable with regard to plant population but more specific with regard to effect on stem length. Herbicide combinations of napropamide and bifenox cause a reduction in both plant population and stem length. Prometryn, oxyfluorfen, and sodium azide had no effect on plant population or growth when compared to plants in the control plots.

Pinus taeda. All herbicides and herbicide combinations, except napropamide wettable and bifenox wettable at the 3.4 and 6.8 kg a.i./ha applied immediately after seeding, did not reduce plant population below the control and none of the herbicide treatments reduced stem length.

Table 2. The effect of preplant soil fumigant (sodium azide) and preemergence herbicides applied soon after seeding on the number of four hardwood and one coniferous species sown in the fall.

Treatment		Tree population (no. of trees/3 m^2)				
Herbicide	kg,a.i./ha	*Quercus rubra*	*Liriodendron tulipifera*	*Cornus florida*	*Juglans nigra*	*Pinus taeda*
Control	—	49 a[1]	89 abc	47 ab	57 a	211 ab
Sodium azide G	400	49 a	102 a	38 ab	54 a	207 ab
Oxyfluorfen E.C.	0.3	56 a	57 cde	39 ab	75 a	155 ab
Oxyfluorfen E.C.	0.6	45 a	65 bcd	25 ab	63 a	247 ab
Prometryn W.P.	0.7	62 a	97 ab	17 b[2]	67 a	227 ab
Prometryn W.P.	1.4	52 a	94 ab	77 a	62 a	281 a
Napropamide W.P. and bifenox W.P.	1.7 3.4	31 a	44 de	15 b	78 a	183 ab
Napropamide W.P. and bifenox W.P.	3.4 6.8	51 a	32 e	2 b	73 a	94 b
Napropamide G and bifenox W.P.	1.7 3.4	30 a	56 de	21 b	65 a	220 ab
Napropamide G and bifenox W.P.	3.4 6.8	46 a	31 e	17 b	50 a	126 ab

[1] Means wtih the same letter are not significantly different at a k ratio = 100 as determined by Duncan/Waller multiple range test.
[2] Losses due to handweeding.

Table 3. The effect of a preplant soil fumigant (sodium azide) and preemergence herbicides applied soon after seeding on the mean stem length of four hardwood and one coniferous species sown in the fall.

Treatment		Average stem length (cm)				
Herbicide	kg,a.i./ha	*Quercus rubra*	*Liriodendron tulipifera*	*Cornus florida*	*Juglans nigra*	*Pinus taeda*
Control	—	16 a	37 a[1]	27 ab	50 a	12 a
Sodium azide G	400	17 a	41 a	28 ab	49 a	12 a
Oxyfluorfen E.C.	0.3	15 a	35 a	23 abc	50 a	13 a
Oxyfluorfen E.C.	0.6	15 a	40 a	24 abc	44 a	14 a
Prometryn W.P.	0.7	15 a	37 a	20 abc	47 a	12 a
Prometryn W.P.	1.4	10 a	30 a	32 a	38 a	11 a
Napropamide W.P. and bifenox W.P.	1.7 3.4	8 a	27 a	12 cd	48 a	12 a
Napropamide W.P. and bifenox W.P.	1.7 6.8	11 a	29 a	1 d	41 a	11 a
Napropamide G and bifenox W.P.	3.4a 6.8	12 a	36 a	16 bc	42 a	11 a

[1] Means with the same letter are not significantly different at a k ratio = 100 as determined by Duncan/Waller multiple comparison procedure.

DISCUSSION

It is apparent from this study that there exists large differences in susceptibility of hardwood species to preemergence herbicides. Although combinations of napropamide and bifenox provided good weed control, they reduced the population and mean stem length of *C. florida* and *L. tulipifera* seedlings, but did not reduce the population or mean stem length of *Q. rubra* and *J. nigra* seedlings. Since acceptable weed control was achieved using 1.7 and 3.4 kg a.i./ha of napropamide and bifenox, these lower concentrations would increase its margin of safety and extend its use for weed control in seedbeds of *P. taeda*. There appears to be no advantages of using granular napropamide over wettable powders. Of the herbicides tested, oxyfluorfen provided acceptable weed control and appears safe for use with all species tested except *L. tulipifera*. Since oxyfluorfen is labelled for weed control in coniferous seedbeds, it appears that it could be used at 0.3 kg a.i./ha soon after seeding *Q. rubra*, *J. nigra*, and *C. florida* in the fall.

Although prometryn did not appear to reduce plant populations or mean stem length of any of the species tested, it did not provide adequate weed control. The poor weed control experienced with sodium azide as a preplant fumigant makes it unsatisfactory for this application. Previous studies conducted with sodium azide at these nursery facilities have been variable and inconsistent.

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JUNIPER PRODUCTION WITHOUT HERBICIDES

ART VANDERKRUK

John Connon Nurseries, Limited
P.O. Box 200, Waterdown
Ontario, Canada LOR 2HO

Let me say at the outset that I am not against herbicides nor am I against the use of them. In fact our nursery makes limited use of herbicides such as Devrinol, Gramaxone, Ronstar, Roundup, Simazine, and Treflan. Devrinol and Ronstar are on a trial basis only because neither of these are registered for nursery use in Canada. Ronstar probably will not be registered since the manufacturer is reluctant to spend the money required to have it tested. The estimated cost to obtain a label for a crop is about $1,000,000.

As I mentioned, we are not against the manufacture or the use of herbicides, but we are against the reckless use of chemicals. Many farms in our land are suffering from a shortage of earthworms and beneficial bacteria, the "living phase" of the soil, so vital to produce superior crops.

God did not intend for us to abuse the soil, rather we are to be good stewards of it. Future generations will also need to make a living from the land. I believe that the fewer chemicals we use the better off we are.

We have found that certain *Malus* and *Tilia* cultivars, for examples, will react to Gramoxone (Paraquat). We also suspect that with a heavy rainfall, severe stem splitting can occur on *Acer platanoides* 'Crimson King' after Gramoxone treatment. In order to obtain good weed control in containers when using Ronstar G you must use the high rate of 200 lb/acre which will discolor the plant to the point where blue or green becomes grey and plant growth is reduced. It has also been our

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experience that it is virtually impossible to produce junipers on land where a high rate of Atrizine has been used on previous crops such as corn. These are some of the reasons why we limit the use of herbicides.

Allow me then to show you how we produce our conifers, junipers in particular, without herbicides and still manage to make a profit. We begin at our propagation department. Cuttings are taken from first and second year blocks only, never from saleable plants.

After rooting has taken place the cuttings are potted into peat pots, 36 to a flat and placed into polyhouses were they are grown for the season. The houses are then covered with a 4 mil opaque poly for winter protection. All of our peat-pot liners are covered with an additional sheet of poly for added protection, the idea of a tent within a polyhouse. (Table 1).

Table 1. Costs involved in producing rooted cuttings and grafting understocks of juniper.*

	Cost per plant	
Materials and Labor	Rooted cutting	Grafting understock
Cost of cutting	$0.04	$0.06
Take cuttings, cut, dip & stick	0.06	0.06
Rooting medium	0.005	0.005
Heat & hydro	0.04	0.04
Greenhouse plastic	0.01	0.01
Allowance for losses — 20%	0.03	0.035
Pots — peat pot/whale hide pot	0.03	0.06
Potting	0.03	0.03
Soil	0.03	0.03
Chemicals & fertilizers	0.01	0.01
Polyhouse plastic	0.005	0.00
Weeding	0.005	0.005
Irrigation	0.01	0.01
Depreciation, land, repair & maint.	0.015	0.015
Overhead & administration*	0.00	0.00
Total cost	$0.32	$0.37

* Calculated at the end of the production cycle

For grafting understocks we use *Juniperus virginiana* 'Glauca Hetzi'[1]. When rooted, these cutings are potted into long-lasting Whale Hide pots, which will last long enough to take the plants through the grafting procedure and into 1-gal containers. These plants are also placed into polyhouses but are then brought back into the greenhouses in October or November in order to prepare them for grafting (Table 1).

The grafting process is the standard method used in most nurseries. We use a side veneer graft and place them in bot-

[1] Bot. Ed. There is no such name; this is either *J. virginiana* 'Glauca' or *J. chinensis* 'Hetzii'.

tom heated ground benches covered with poly to make a humidity tent which allows for quick callusing. Ventilation takes place after good callusing has occured and the plants begin to grow. The poly is completely removed when the understock is pruned back. In May we pot all grafted stock into 1-gal containers; these are placed in polyhouses for summer growing and are then covered for winter protection (Table 2).

Table 2. Costs of propagating junipers by grafting.

Materials and Labor	Cost per graft
Cost of understock	$0.37
Pruning of understock	0.03
Taking scions	0.02
Grafting	0.16
Peat moss	0.01
Greenhouse plastic	0.025
Heat & hydro	0.095
Allowance for losses — 5%	0.035
Pruning & elastic removal	0.05
1 Gal.* containers	0.17
Soil	0.15
Potting	0.08
Polyhouse plastic	0.015
Miscellaneous supplies	0.02
Labour — weeding, irrigation, spraying	0.01
Depreciation, land, repair & maintenance	0.06
Overhead & administration**	0.00
Total cost	$1.30

* trade designation
** calculated at the end of the production cycle.

Cuttings and grafted liners are usually planted in the field in late May after the spring shipping season. The soil is prepared in the conventional manner: plowing, fertilizing, discing, cultivating, and harrowing. The cuttings are then planted by machine and secured by firming the soil around the plant by foot to insure quick moisture uptake. The plants are then irrigated very thoroughly. In extremely hot weather, as is sometimes the case in May, we treat the plants with an antidesiccant. This is done prior to planting. By following these practices we seldom lose a plant (Table 3).

Grafts are planted by hand since they are in 1-gal containers. Furrows are drawn in the field and the plants are planted at a spacing of 4 ft × 18 in. Once planted, the grafts are thoroughly soaked with about 2 in of water. We do not plan to develop a machine for this job because we are going to shift the production of all junipers from the field to containers.

After-care includes pruning, spraying, and cultivating. Pruning is done annually right after the snow has disappeared

in late winter. Hedge clippers are used for most prunings. The upright junipers receive one final pruning in mid-August, just prior to becoming saleable. This is always done by knife to avoid unsightly pruning marks made by the hedge clippers.

Table 3. Production costs for field-grown junipers.

Cost factors	Upright *junipers*	Spreading *junipers*
Land*	$0.075	$0.075
Fertilizers & green manure	0.08	0.08
Soil preparation	0.015	0.015
Plant	1.30	0.32
Planting	0.15	0.075
Irrigation	0.03	0.03
Cultivation	0.055	0.055
Hoeing	0.20	0.20
Pruning	0.52	0.30
Spraying	0.01	0.01
Allowance for losses — 10%	0.24	0.12
Pots	0.61	0.49
Digging	0.40	0.40
Grading & labels	0.05	0.055
Polyhouse plastic	0.125	0.125
Order assembly & loading	0.40	0.30
Depreciation, repair & maintenance	0.30	0.30
Overhead & administration — 12%	0.57	0.37
Total cost	$5.13	$3.32

* based on land rental of $100 per acre

Spraying is done by using modified peanut sprayers. These sprayers are used in our entire nursery and are modified by changing the mist blowers to pivot up and down as well as being able to rotate from left to right. Chemicals such as Benlate, fixed copper, Kelthane, and Thiodan are used to protect plants from juniper tip blight, mites and insects. We try to limit ourselves to three sprayings per season beginning in late June.

Cultivation is done on a regular basis, mostly with 140 International tractors. We have one 140 International Hi-Clear which is used extensively on the taller growing plants. Once the evergreens become 36 in or more in height we make use of our Poly-Bob tractor which is completely adjustable by means of hydraulics. This machine has a clearance of 8 ft and is capable of cultivating trees up to 9 and 10 ft tall, depending on their ability to flex. After a rainy spell, when the weed seeds have germinated and we have been unable to cultivate, we have to go through the rows twice to cover all the weeds. The idea is to cover the weeds with soil in order to choke them. We try to hoe right after cultivating when the soil is loose and easy to move. In late fall when cultivation is impossible we

still hoe. Seeds of such weeds as shepherd's purse, chickweed, and grasses will germinate and grow even at low temperatures. It is important to clear them away from the plants to avoid that extra work in the spring. It also helps to keep the mouse population to a minimum.

We plant 2 rows of low growing plants between our blocks of uprights. This practice is followed throughout the nursery in all tall growing crops. Our blocks are at 40 ft spacings, 10 rows of 4 ft. This spacing enables us to reach our plants easily with fertilizer, pesticides, fungicides, stakes, etc. At harvest time these rows are removed first and the space becomes a roadway which makes digging and removal of the plants more efficient.

Most of our evergreens are dug by hand and placed into fiber pots. We first undercut the rows of plants with our rootpruner; this makes the task of lifting plants easy since all tap roots are cut. It is then a simple procedure to dig around the plant and lift the soil ball into the pot, firming it with the handle of the spade. The plants are then soaked by irrigation within 12 hr of digging unless, of course, natural rainfall occurs within that time. We believe that this watering is of utmost importance for a high survival rate and top quality. We did develop a 2-row digger for this job but found that it was just as efficient to dig by hand.

Most of the evergreens are graded in the field. This makes storage and assembling of orders more efficient. It also reduces grading costs. It is very easy to grade in the field because of the available space. Plants below the acceptable standard are not tagged and are placed in a separate polyhouse. These plants are then pruned and spaced the following spring and allowed to grow on in the pot until they become saleable, which is usually after one flush.

All of our saleable blocks of evergreens are dug in the fall and brought into polyhouses for the winter. We use wagon trains to haul them out of the fields. Our road laws restrict us to 65 ft so we have built wagons with two layers instead of one. These wagons, of course, will only carry spreading jupers on the bottom layer and total an average of 220 11-in pots.

All our polyhouses used for winter storage are covered with opaque plastic to minimize temperature fluctuations. In early spring when temperatures climb we vent our houses first by opening the top-half of the Dutch doors. When high temperatures persist we vent the center of the house by cutting round holes in the plastic. When all danger of snow and severe weather is past the poly is removed.

The bulk of our orders are shipped out on 4 × 8 ft skids with 2, 3, or 4 layers, depending on the type of stock to be loaded. These skids are filled right at the polyhouses. The plants are not handled again, thus giving a substantial saving of labour while keeping freight losses negligible. Six thousand pound forklifts are utilized to carry the skids to the assembly areas and to load the trailers. Eleven of these skids fill a 45 ft trailer.

In answer to the question, "are herbicides really necessary?", many people believe they are; but I wonder if these people calculate the cost of the herbicides and tally up the losses over the years in actual damage and/or reduction in growth, poor appearance, etc. In my opinion, if we can produce plants without herbicides and can continue to be competitive, I prefer to do without them and believe them unnecessary in our industry. To stay competitive we may have to develop systems that are much more labour saving to offset the added expense of cultivation and hoeing.

WILL THE PROPAGATOR HAVE THE PESTICIDES HE NEEDS NEXT YEAR?

RAY BRUSH

American Association of Nurserymen
1250 Eye Street, N.W. Suite 500
Washington, D.C. 20005

Will you have the pesticides you need next year? My answer is maybe! Many of you will have the most of the pesticides you need for next year. However, some of you will not be able to obtain or use specific pesticides that you would like to have.

With the passage of the 1972 amendments to the Federal Insecticide, Fungicide and Rodenticide Act, nurserymen began experiencing difficulties in obtaining the pesticides they needed to: 1) produce healthy vigorous plants, and 2) to meet state or federal quarantine certification requirements. Keep in mind that under the first need, you, like other segments of agriculture, are only interested in efficient control of the common pests so that your nursery plants are healthy, vigorous, and of a good quality that will readily sell. In contrast, under the second need, you have to maintain your plants completely free of some hazardous pests. These are specific pests not widely distributed in the United States. Historically, the nursery in-

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dustry has readily complied with these requirements because they recognize exotic pests might be moved on nursery plants to noninfested areas of the country. Quarantine pests such as the imported fire ant, golden nematode, and witch weed do not attack nursery plants. Other quarantine pests, such as gypsy moth and Japanese beetle, will attack nursery plants but are not normally serious pests in the nursery. Quarantines have been invoked to prevent the long distance or artificial spread of these exotic pests to protect other segments of agriculture.

Our greatest priority for pesticide needs in 1984 will be pesticides to meet quarantine requirements. Under the 1972 amendments to the Federal Insecticide Fungicide Rodenticide Act, the long residual pesticides which nurserymen had used to meet the quarantine certification requirements for Japanese beetle, white fringed beetle, European chafer, and imported fire ant were taken away when registration for use on general agricultural crops was cancelled. The extended hearing on the registration for dieldrin and aldrin terminated in April, 1976, with the manufacturer withdrawing the label and discontinuing sales in the United States. That hearing was promptly followed by the chlordane/heptachlor hearing which was terminated in a negotiated settlement in March, 1978. The signator parties in that settlement were: Velsicol Chemical Company, the manufacturer of chlordane and heptachlor; United States Department of Agriculture, who in cooperation with Velsicol defended the nursery industry uses of chlordane and heptachlor; Environmental Protection Agency; and Environmental Defense Fund. At the time of the settlement, the Agriculture Research Service of the U.S. Department of Agriculture indicated that alternate chemicals to chlordane for the nursery industry's use in meeting quarantine requirements should be on hand by January, 1980. Those two years plus three more have now elapsed, and the nursery industry still does not have a replacement for chlordane and heptachlor. In addition to periodically reminding the United States Department of Agriculture of this promise, in 1983 the American Association of Nurserymen (AAN) took that promise to the Congress seeking its support in pressing USDA to fulfill its promise. We do not see any relief as yet.

I am pleased to report that Harvey Ford, the Deputy Administrator of APHIS (Animal and Plant Health Inspection Service), USDA, assured AAN in early December 1, 1983, that his staff will work with the industry. For example, if a nursery is shipping plants needing Japanese beetle certification and, if the land was treated in the past with chlordane, and there is a reasonable likelihood that there is sufficient residue remain-

ing, his staff will work with the nurserymen and his state nursery inspectors in taking soil samples and running a bioassay. This test would determine if the chlordane residual is sufficient so that the plants can be properly certified for shipment to Canada or to one of the four states requiring certification. AAN is also pressing for USDA's Agricultural Research Service to continue testing the pesticide Oftanol to determine whether or not this chemical can be approved for quarantine certification uses. Tests at USDA's Japanese beetle laboratory at Wooster, Ohio were initiated two years ago with both field and container grown nursery plants. The results to date are not sufficiently conclusive to authorize the use of this chemical for nursery certification purposes. For at least four years now that chemical has been used by APHIS in treating airports for Japanese beetle where there exists a serious risk of moving adult beetle via aircraft to non-infested areas.

I am also pleased to report that Mike, Inc., of North Carolina has notified EPA of their intent to continue their registration of EDB (ethylene dibromide) for emergency treatment of nursery plants to meet certification requirements. I was told this past week that the supplemental data for revising the label has been submitted to EPA. Their pesticide Mike Tox 434 is applied by injecting it into the soil ball or the container medium. As you can see, we still have need for pesticides to meet the imported fire ant and Japanese beetle quarantine certificate requirements. In the case of imported fire ant, it is recommended that you judiciously use any limited quantities of chlordane that you may have left. You may want to use it for treating only those fields or those batches of container media mix that may be used in producing plants that you expect to market in states where certification is needed. Also, it is suggested that you use the pesticides which have been approved for economic control of imported fire ant on other agricultural land, park lands and playgrounds for treating any fire ant mounds on your land that may be adjacent to your nursery production. By reducing the adjacent fire ant population to a minimum, you can reduce the risk of your nursery field becoming infested and hopefully get by until we do have a replacement for chlordane.

I'm pleased to report that much progress has been made in recent years in obtaining registration for nursery uses of those pesticides you need for economic control of insects, diseases, weeds and other pests. One of the 1972 amendments of FIFRA was Section 2(ee) which made it illegal to use any registered pesticide in a manner not named on the label. This meant that the pest and the crop both needed to be named on the label.

In 1977 at the request of AAN, IR-4 (InterRegional Project #4) initiated work to coordinate obtaining the data needed for registration of pesticides for nursery crops. IR-4 was initiated 20 years ago by the State Agricultural Experiment Stations and the USDA to facilitate registration of pesticides for minor agricultural crops. The Nursery Pesticide Needs Survey conducted by AAN in 1977 produced the initial list for IR-4 to develop their priorities for registration of nursery uses. Because of a late start in really zeroing in on the nursery pesticide registration needs, in 1981 there was still a delay of 5 to 7 years from the time a pesticide was first registered for use on a food or feed crop before a registration was being obtained for use on nursery crops.

In 1978, the AAN, in cooperation with other agricultural groups, sought and obtained a Congressional amendment to Section 2(ee) to permit the application of a pesticide against any target pest not specified on the label *if* the application to crop, animal, or site was specified on the label. This helped but did not give the total relief that the industry needed. This modification in the Act plus the work being done through IR-4 and special funds made available by USDA's Agriculture Research Service for nursery pesticide research has reduced the time lag between first registration for use on a food or feed crop and registration for nursery use to 3 to 4 years currently. The average lag should soon be reduced to 2 to 3 years. Now as soon as a new pesticide is made available for experimental research, IR-4 cooperators are setting up experiments to obtain data for nursery crop use registration. It is anticipated that the lag will not be reduced to less than an average of 2 years. Because of the high value per acre of nursery crops, and the many kinds of plants that we are growing, there is a higher potential for phytotoxic liability problems than with other agricultural crops. It is understandable that chemical manufacturers do not want their new pesticides to be registered for nursery use until there has been plenty of opportunity to obseve if any toxicity problems might arise.

AAN, your extension specialists, and pesticide manufacturers recommend that no matter how highly recommended a new pesticide may be when it has been registered for nursery use, try it on a very limited scale under your cultural conditions and practices to assure yourself that you will not be exposing your crops to phytotoxicity problems. In the past, there have been nurserymen who have not followed this advice and have applied a new pesticide for the first time on their whole crop. Unfortunately, such a lack of precaution has resulted in serious economic crop damage. Some growers have made claims against the pesticide manufacturer. The cost to

settle such liability claims can quickly erase the manufacturers profit from nursery sales of that product. As a businessman you can see why some chemical companies are not anxious to have early registration for nursery use. Therefore, if you want the early use and in fact, any use of a pesticide, cooperate with the chemical manufacturer by testing on a limited basis to determine any peculiarities that may arise when a pesticide is used on your crops under your cultural conditions and practices. If any problems arise, the chemical company, or the extension specialists in your state, can assist you in adjusting your practices to avoid toxicity problems.

There is a provision in the 1972 amendments which is helping nurserymen obtain the legal use of pesticides needed for effective control of common pests. It is outlined in Section 24(c) of the Act. It is a state registration, known as a 24(c) or special local needs registration. A pesticide which has already been federally registered for some other use may be a candidate for state special local needs registration. When the State Pesticide Registration Authority grants such a registration, EPA is notified by the state and, unless EPA disapproves that registration within 90 days, the state registration stands. Such a registration is only good in the state in which it has been granted. A recent example is the 24(c) registrations obtained in California, Oregon, Michigan, and Ohio for Furadan 4F to be used on nursery plants to control black vine weevil. If you want information on a 24(c) registration, check with the extension specialist at your land grant university to make sure that the pesticide you want to use is legal in your state and learn of any restrictions which may exist in the registration. Keep in mind that because Furadan 4F is legal in California, Oregon, Michigan, and Ohio it does not mean that it is legal in any other state.

A 24(c) or state special local needs registration is an exception to the rule that pesticides with national nursery use registration are also registered in your state. Another exception to this rule is that some states, such as California, Massachusetts, Connecticut, Wisconsin, and Colorado, have at times chosen not to register a pesticide in their state for nursery use even though there is a federal registration for the same use. States do have that right and you need to be aware of it.

AAN is endeavoring to bring to your attention, in its publication *UPDATE*, additional nursery uses as the pesticide labels are expanded. Check with the extension specialist in your state to determine if these added uses have been registered in your state. If your extension specialists cannot answer the question call me at the AAN office in Washington, and I will give you the name and telephone number of the State Pesti-

cide Registration Official in your state so that you can check for yourself.

As you can see the 24(c) or state special local needs registration provides an opportunity for registrations to protect crops that may be important in your state but are not that important throughout the country.

In the months ahead it is going to be very important that the nursery industry and other segments of agriculture speak out in opposition to the "Harper's Ferry Bill" introduced by Congressman Harkin of Iowa. This bill would greatly revise FIFRA. It would restrict EPA and state discretion to grant "special local needs" registrations. Another proposed change would be that the person applying the pesticide would have to be a certified applicator to apply restricted pesticides. At the present time, the applicator, if he is not certified, must be under the direct supervision of a certified applicator. Other objectional revisions would: allow any affected person to request a public hearing on a registration; amend the procedures for becoming a certified applicator; require you as a private applicator to keep additional spray records; restrict EPA discretion in granting emergency registrations; transfer farm worker jurisdiction to OSHA; etc. These and other modifications were developed by a coalition of anti-pesticide groups which met at Harper's Ferry early in 1983. Action on this bill was deferred by Congress in November 1983, at the request of EPA Administrator Ruckelshaus who as a new appointee had not had time to fully analyze the bill. It is sure to arise again in 1984, probably somewhat revised from the 1983 version. Such legislation is expected to receive considerable discussion during the 1984 election year. When the legislation is introduced, we will alert you to it and to those portions which, if enacted, would be detrimental for the nursery industry.

Early each year, IR-4 headquarters contacts AAN asking if there are new pesticide registration needs of the nursery industry that should be incorporated into their work scheduled for that year. Keep this in mind and let us know of your special needs.

In closing, remember just because another nursery legally uses a pesticide in its state does not necessarily mean that it is legal for you to use it in your state. Before using a pesticide make sure that it is registered in your state. Whenever you are using a new pesticide make sure that you test it on a very limited basis with your soils, climate, and cultural practices. If you will follow this advice you will help greatly in making sure that the nursery industry will have the legal use of the pesticides it needs.

Thursday Afternoon, December 8, 1983

The Thursday afternoon session convened at 1:30 p.m. with Clayton Fuller serving as moderator.

PROPAGATION OF *PRUNUS PERSICA* CULTIVARS BY CUTTINGS

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Abstract. Semi-hardwood cuttings of 6 cultivars of peach (*Prunus persica*) were successfully rooted by wounding, dipping in 2500 ppm IBA and misting. Cuttings of each cultivar were grown to 30 in trees and transplanted in the field for further study. Hardwood cuttings of 'Cresthaven' and 'Redhaven' were also successfully rooted by wounding and dipping in 250 and 500 ppm IBA. Although callus formation on 'Rio Oso Gem' was achieved with IBA treatments, no formation of callus or roots occurred with 'Loring'. Hardwood cuttings were not successfully transplanted.

INTRODUCTION

Most commercial nurseries propagate peach trees by budding on seedling rootstock. June-budded and dormant-budded trees are planted by peach growers in New Jersey. June-budded trees are less expensive to produce than dormant-budded trees. Both are generally offered to commercial orchardists for $2.25 to $5 per tree, depending on many factors.

Nursery stock purchased from commercial nurseries has not been of consistently high quality and has not always been true-to-name. Peach cultivars purchased on the preferred seedling rootstocks of 'Lovell' and 'Halford' are variable in performance and have been short-lived, particularly on old peach orchard sites. Growers are not satisfied with these rootstocks and others available from nurseries.

In recent years, growers and researchers have attempted to offset early tree loss by planting more trees per acre (high density) (4). The land area is covered with a tree canopy earlier in the orchard's life. This results in earlier economic peach yields (3). Growers want a less expensive tree to reduce these orchard establishment costs. Some growers would also prefer a system of producing trees that is easier and less costly so they can grow their own and have more direct control of quality and trueness-to-name.

Plant propagators and researchers have been testing and investigating the propagation of peach trees by cuttings for many years. Some of the earliest research was reported by Hartmann in California almost 30 years ago (7,8,9). Researchers in Georgia, Israel, California, Mississippi, and the southern hemisphere have successfully rooted peaches from semi-hardwood and hardwood cuttings (1,2,7,9,13). Plantings of self-rooted peaches have also done well. Some blocks are 15 years of age. Approximately 750,000 self-rooted peach trees were planted and are producing in New South Wales, Australia (5).

Based on research in Missouri (6) and the work of Marini in New Jersey (11,12) research and demonstrational plots were undertaken and established in Gloucester County, New Jersey in 1982 and 1983 to develop a system for the propagation of peach trees from cuttings on a commercial scale. Systems of propagating trees from both semi-hardwood and hardwood cuttings were researched. A hardwood system would be preferred because it would not be used during the harvest season. Plantings were established that could be studied and evaluated for tree efficiency and longevity.

MATERIALS AND METHODS

Experiment 1 — Semi-Hardwood Cuttings. Current season's growth from the terminal portion of shoots of mature, vigorous, healthy trees of 'Autumnglo', 'Loring', 'Redhaven', Jerseyqueen', 'M.A. Blake', and 'Rio Oso Gem' were collected on August 10, 11, and 12, 1982. Twelve hundred 8 to 10 in. cuttings were made from terminal shoots that were approximately 5/16 to 3/8 in diameter.

Shoots were soaked in water until all leaves were stripped except 3 to 5 on the terminal end. All cuttings were wounded on opposite sides, 1 in. from the basal end, submerged for 5 sec, 1½ in deep in a 2,500 ppm IBA solution (potassium salt in water), and planted in a prepared rooting medium. The rooting medium consisted of equal parts of peatmoss, perlite, and vermiculite. The medium was contained in 5 × 5 ft movable trays, 6 in. in depth. Cuttings were planted 1½ in deep and 4 in apart.

A pole shed was built in an outside location sheltered from the wind. Both tops and sides were covered with 6 mil poly. The polyethylene on the sides was rolled up on warm and still days. The top panel was also covered with lath.

Along the north side of the trays a misting system was constructed using split connector Mist-O-Matic nozzles on a ¾-in pipe. A timer opened and closed a solenoid valve to regulate misting.

Cuttings were misted starting with 5 sec of mist every 5 min during the day. Misting was discontinued after dark. The amount of water was gradually decreased as air temperatures were lowered and rooting progressed.

Misting was stopped on September 15, 1982, and occasional hand watering kept the cuttings and medium moist. The trays of cuttings were moved by forklift into a well ventilated apple storage room on November 20, 1982, and maintained until early February, 1983. The cuttings were watered as needed.

All cuttings were removed from storage on February 18 to 21, 1983, and planted in 1-gal plastic bags in a mix identical to the rooting medium plus a small amount of dolomitic limestone. Cuttings were watered by hand and fertilized every 10 days to 2 weeks with a water soluble fertilizer containing a balance of micro and macro nutrients.

Peach trees 26 to 30 in high were planted by hand in trenches plowed in an old apple orchard site on May 19 to 25, 1983. The 1-gal poly bags were split and removed during the planting operation. Measurements on tree height, diameter, trunk caliper, and leaf tissue analysis were taken during the summer of 1983.

Experiment 2 — Hardwood Cuttings. Hardwood cuttings of 'Cresthaven', 'Rio Oso Gem', 'Redhaven', and 'Loring' were taken on February 17, 1983, from vigorous, healthy peach trees. Cuttings 6 to 8 in long were selected from the past summer's growth. Cuttings from both the terminal and the basal portion of the shoot were used. Each cultivar was treated as follows:

1. Twenty-seven cuttings were tied, nine per bundle;
2. Twenty-seven cuttings were tied, nine per bundle and dipped 1½ in. deep in a 250 ppm IBA solution (potassium salt in water) for 10 sec;
3. Twenty-seven were wounded 1-in. in length on opposite sides of the basal portion of the cutting, tied in bundles of nine and dipped 1½ in deep in a 250 ppm IBA solution (potassium salt in water) solution for 10 seconds;
4. Twenty-seven cuttings were tied, nine per bundle, and dipped 1½ in deep in a 500 ppm IBA water solution (potassium salt in water) for 10 seconds;
5. Twenty-seven cuttings were wounded 1-in in length on opposite sides of the basal portion and tied in bundles of nine, and dipped 1½ in deep in a 500 ppm IBA solution (potassium salt in water).

All bundles were planted 1 ½ in deep and 8 in apart in a tray filled with a rooting medium of equal parts sand, peat-moss, and vermiculite. The tray was filled with 5 in of medium. Two electric heating cables were buried 4 in deep. Soil temperatures were maintained at 55 to 70°F. Cuttings were hand watered as needed to keep both soil and cuttings moist. Clear 6 mil polyethylene was used to cover the cuttings except on very hot days. Cuttings were removed, graded, and rated by root and callus development on March 12, 1983.

RESULTS

Semi-hardwood Cuttings. All cultivars rooted well from semi-hardwood cuttings. (See Table 1). 'Autumnglo' and 'Loring' had the highest rooting percentage. The root system was excellent with many fine, fibrous roots. Major causes of cutting loss were fungus infection identified as a *Pythium* and *Phytophthora* species. Most cuttings broke dormancy 2 weeks after transplanting. Cuttings grew rapidly in the greenhouse with temperatures maintained between 60 and 70°F. Lateral shoots were removed after a shoot broke dormancy to encourage strong, straight growth. Some tree loss occurred during the pruning process. This loss and further infection with a *Phytophthora* sp. was the cause of plant loss in the greenhouse. A manganese deficiency was corrected with additional applications of trace elements.

Table 1. Number and percent rooting and field planting of six cultivars of *Prunus persica* propagated as semi-hardwood cuttings.

Peach cultivar	Number of cuttings planted	Rooted cuttings transplanted to pots	Potted plants transplanted to field
'Autumnglo'	200	196 (98%)	191 (96%)
'M. A. Blake'	200	179 (90%)	169 (85%)
'Loring'	200	174 (87%)	154 (77%)
'Jerseyqueen'	200	178 (89%)	167 (84%)
'Redhaven'	200	199 (99%)	198 (99%)
'Rio Oso Gem'	200	178 (89%)	168 (84%)

Most trees from rooted cuttings exceeded 30 in in height and were ready for field planting on May 10, 1983, 81 days after potting. Planting was delayed until May 19, 1983, due to wet field conditions. Young, succulent trees were staked because of cool, wet, windy weather after planting. Thirty percent of some cultivars were lost during the early growing season with *Phytophthora* sp. root rot. Ridomil 2E at the rate of 2 qt/A was used to control the disease.

Trees of each cultivar were planted in a randomized block with the same cultivar on 'Lovell' seedling rootstock. After one

summer's growth, the surviving trees were similar in size to those on 'Lovell' roots. Nutrient leaf analysis has shown no difference between 'Lovell' budded trees and those on their own roots.

Approximately 18,000 semi-hardwood cuttings have been rooted by Gloucester County fruit growers during the summer of 1983. No data has been recorded on the rooting percentage to date.

Hardwood Cuttings. Harwood cuttings appeared to be more difficult to root than semi-hardwood cuttings. A higher percentage of 'Cresthaven' rooted when treated with IBA than any other cultivar. (Table 2). 'Redhaven' rooted better than 'Loring' and 'Rio Oso Gem' when wounded and treated with IBA. Wounding significantly improved the rooting percentage of both 'Redhaven' and 'Cresthaven'. The average of all showed a higher rooting percentage when wounded regardless of the IBA concentration.

Table 2. The effect of wounding and IBA treatment on the rooting of hardwood cuttings of *Prunus persica* cultivars.

	Percent rooted				
	'Cresthaven'	'Rio Oso Gem'	'Redhaven'	'Loring'	All cultivars
Control	0[z]a	0 NS	0 a	0 NS	0 a
250 ppm IBA	44 b	11	15 a	0	18 a
250 ppm IBA + wounding	93 c	4	48 b	15 b	40 b
500 ppm IBA	48 b	15	7 a	4	19 a
500 ppm IBA + wounding	96 c	4	59 b	11	43 b

[z] Means separated using Duncan's New Multiple Range Test, 5% level.

Table 3. The effect of wounding and IBA treatment on rooting and callus formation of hardwood cuttings of *Prunus persica* cultivars.

	Combined Percent Rooting and Callus Formation				
	'Cresthaven'	*'Rio Oso Gem'*	*'Redhaven'*	*'Loring'*	*All cultivars*
Control	0[z]a	0 a	0 a	0 NS	0 a
250 ppm IBA	86 b	70 b	86 b	38	70 b
250 ppm IBA + wounding	100 b	14 a	86 b	40	60 b
500 ppm	96 b	56 b	96 b	4	74 b
500 ppm IBA + wounding	96 b	14 a	92 b	52	64 b

[z] Means separated using Duncan's New Multiple Range Test, 5% level.

Callus formation appears to occur prior to rooting of peach cuttings. The effect of all treatments on combined callus formation and rooting was analyzed. (Table 3). All cultivars had significantly higher combined percent rooting and callus formation when treated with IBA. Wounding did not increase the combined percent callus and rooting on 'Redhaven' and 'Cresthaven', and reduced the percentage with 'Rio Oso Gem'.

'Loring' did not root or callus with any treatment under these conditions. Transplant survival of rooted cuttings was less than 10% and zero for those with callus.

DISCUSSION

The rooting of peach cultivars from semi-hardwood cuttings can be done cost-effectively by fruit growers, nurserymen, and others. Cost of rooting and growing trees was less than $1 per tree although this figure did not include greenhouse overhead and operation. After 7 years of testing and considering the work of Ernest Christ and Richard Marini in New Jersey and others, it appears the following peach cultivars can be rooted successfully from semi-hardwood cuttings: 'Redgold', 'Sunglo', Reliance', 'Burbank', 'July Elberta', 'Lovell', 'Autumnglo', 'Jefferson', Redhaven', 'Cresthaven', 'Rio Oso Gem', 'M.A. Blake', 'Loring', 'Early Loring', 'Slaybaugh', 'Special Jerseyqueen', 'Zee Rio', 'Casselloqueen', 'Springcrest', 'Bicentennial', 'Cardinal', 'Coronet', and 'Redskin'.

While the rooting of hardwood cuttings would be the preferred procedure to distribute labor requirements throughout the year more work is needed to increase rooting and increase transplant survivals before recommendations can be made. Based on a review of the literature, observations in grower orchards, and evaluation of older plantings in New Jersey, it appears that self-rooted trees are as long-lived and efficient as trees on available seedling rootstocks but more testing needs to be done.

Since certain rootstocks historically have had a profound and beneficial effect on the scion cultivar of most fruit types it is hoped that a beneficial peach rootstock can be developed that is propagated asexually and offered by commercial nurseries. The offering of quality peach trees that are true-to-name for the cultivar labeled will reduce the interest of fruit growers trying to become involved in this highly specialized enterprise.

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LEN STOLTZ: Did you try any other time than February with your hardwoods? From the Australian work it looks like January 15th to 30th, might be better.

JEROME FRECON: No.

CHARLIE PARKERSON: When did you harvest the cuttings?

JEROME FRECON: Six weeks after sticking.

BOB OSBORNE: Have you thought of the possibility of moving your hardwood cuttings directly to the field after callusing? Work from East Malling and some of ours indicates that you get a better take.

JEROME FRECON: That is being done in other parts of the world but I am afraid of soil temperature. Possibly it would work.

DAVE BAKKER: A suggestion that you might try which we use with *Prunus* × *cistena*. Make your cuttings before you have a severe frost and store at freezing in cold storage. In the spring, when the soil is warm enough, treat the cuttings with a No. 3 IBA powder plus Benlate and set on a heating table at 20°C. In 1 to 1½ weeks the cuttings will be well callused and when 1% are showing roots they can be dipped in a clay bath and planted with a mechanical planter.

DEVELOPING AND IDENTIFYING HARDY LANDSCAPE PLANTS

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This presentation will attempt to accomplish three things. The first is to review some background information that provides the basis of our approach to breeding and selection of cold hardy landscape plants. Secondly, I want to discuss a cooperative plant improvement effort that I am promoting. Third, I would like to mention our plant improvement research at the University of Minnesota Landscape Arboretum.

The primary goal in improvement of landscape plant materials is to combine desirable aesthetic and utilitarian qualities with ability to tolerate environmental stresses. The most limiting environmental factor for landscape plants in much of the United States is cold winter temperatures. To incorporate tolerance to such low temperature, an understanding of the physiology and genetics involved is essential. Research has shown that, in simplified terms, cold acclimation is a two-stage sequence, with photoperiod the initial stimulus triggering various metabolic events leading to cold acclimation (14). Cold temperature triggers the second stage of the process. In cases of plant species that are native over a wide geographic area, different geographic ecotypes have evolved with different critical photoperiods triggering growth cessation and initiation of cold acclimation (6,12,13). Research by Pauley and Perry (6) working with *Populus trichocarpa* illustrates the magnitude of these differences. They grew provenance collections from throughout the native range at Weston, Massachusetts, latitude 42° N, and recorded cessation of growth. Plants from a 60° N latitude source ceased growth on June 20 (the period of longest days), while plants from 35° N. latitude were still growing actively on October 28 when the growing shoot tips were killed by frost. Whether difference in winter survival ability of different geographic ecotypes within a species is primarily due to difference in timing of acclimation or whether there is also difference in maximum hardiness is unclear at present. Information on the relationship of provenance to maximum cold hardiness potential is quite limited. Sakai and Weiser (11) found large differences in hardiness between coastal and inland populations of *Pseudotsuga menziesii, Thuja plicata,* and *Tsuga heterophylla* collected in midwinter and hardened in the laboratory prior to hardiness determinations. However,

there was no difference in midwinter hardiness levels of *Populus deltoides* and *Salix nigra* from southern and northern sources tested in the same manner. George, *et al.* (4) tested hardiness levels in January of latitudinal ecotypes of *Quercus rubra*, *Betula alleghaniensis*, *Juglans nigra*, and *Prunus serotina* from provenance collections growing in Michigan and Massachusetts. They evaluated hardiness by exotherm analysis of the freezing point of super-cooled water in stem sections. They found little difference in hardiness levels and no correlation due to latitude of the source in any of the four species. More research is needed to determine how much variation exists in midwinter hardiness capability among different geographic ecotypes of a given species. Research by Sakai (10) and Pellett, *et al* (7) indicate that many species of woody plants can harden to withstand midwinter temperatures lower than those of the zones for which they are recommended. This data might suggest that timing of acclimation is the critical factor. Through coordinated acquisition and breeding efforts, potential exists for development of genotypes capable of growing in colder climates than where they are currently used.

Information on inheritance of cold hardiness factors is quite limited. However, information that does exist indicates that hardiness is a quantitative character. Working with different species of woody plants, Pauley and Perry (6), Dormling, *et al.* (2), and Eriksson *et al.* (3) determined that F_1 plants are intermediate to the parents in time of growth cessation. Zagaja (15) crossed hardy Chinese peaches to commercial cultivars, screened the F_1 generation for winter hardiness, and either selfed or backcrossed F_2 selections to the commercial cultivars. Results indicated that backcross seedlings resembled the recurrent parent in hardiness levels, while individuals were found in the F_2 population that were as hardy as the Chinese ancestor. Clausen and Hiesey (1) crossed different altitudinal ecotypes of *Potentilla glandulosa* then planted F_2 populations at several sites differing in altitude and observed survival over a period of several years. The segregating F_2 population exhibited many recombinations of growth patterns and a widely increased range of adaptability of each general growth form. Some cases of transgressive segregation for adaptation were also noted. Hummel, *et al.* (5) crossed northern and southern latitudinal ecotypes of *Cornus sericea* and compared the F_1 and F_2 populations to the parent plants for initiation of cold acclimation in response to decreasing photoperiods. F_1 populations were intermediate to the parents in response while F_2 populations exhibited a wide segregation in rate of cold acclimation. A few individuals acclimated at the same rate or even slightly

faster than the northern parent and others were equal to or slower than the southern parent.

Results of these studies suggest exciting opportunities for development of adapted landscape plant materials through well planned and coordinated germplasm improvement efforts. Ecotypes of a given species, or perhaps different compatible species, from different geographic areas could be acquired and hybridized. Growing open pollinated seeds of the F_1 population would enhance the germplasm through recombination and segregation from the broadened genetic base. Populations of this enhanced germplasm could then be evaluated at various locations in appropriate areas throughout the U.S. for selection of superior recombinant types combining desirable aesthetic qualities with adaptation to local or regional conditions. If transgressive segregation takes place, as suggested in research by Clausen and Hiesey (1) and Hummel, *et al.* (5), clones could be selected that are adaptable outside of the current use range of even the hardier more widely adapted parent. Selection of superior plants could result in new clones for direct landscape use or in superior parental material for utilization in additional breeding activities.

To achieve the potential suggested by the research just cited, a cooperative approach would be more economical and would yield greater returns for the cost than would projects conducted solely at any one location. For us in Minnesota, we have the limitation of our cold winters. Many species or clones that we might desire to use as parents for their superior aesthetic qualities cannot be easily maintained to flowering age. The F_1 generation also might not be sufficiently hardy. However, if we could get to the F_2 population the potential exists for combining sufficient hardiness with the desired aesthetic qualities in selected individual plants. Others would have the same problem when working for greater cold hardiness. If a cooperative approach could be developed, the initial hybridization could be done at a site with a milder climate, isolated F_2 populations could be grown out there, and open pollinated seed could be collected to produce the F_2 populations. The F_2 populations could then be distributed to several evaluation sites in various areas throughout North America where selections could be made of specific plants that combine adaptation to local environmental conditions with superior aesthetic qualities. Well adapted clones could then be selected for regional use. Thus, the most costly part of the breeding program (the maintenance of parental stock and the initial hybridization for F_2's) would not have to be funded by each state or institution involved.

The idea for this cooperative approach was described in a viewpoint article in the October, 1983, issue of HortScience (9). To give examples of what could be done by this cooperative approach, the genus *Acer* has excellent potential for germplasm enhancement in many different sections of the genus. In the Platanoidea, *A. platanoides* crosses readily with *A. truncatum*, and offers opportunity for development of small shade trees more tolerant to sun scald and other environmental stresses than are current cultivars of Norway maple. The transgressive segregation approach could be used with *A. saccharum* to increase drought and heat tolerance. If *A. saccharum* is compatible with the closely related *A. grandidentatum*, great gains could be made in fall coloration as well as drought and heat tolerance. In the Palmata section, excellent possibilities exists for developing hardier Japanese maple types. *A. pseudo-sieboldianum*, *A. sieboldianum*, and *A. japonicum* could be used to increase hardiness of *A. palmatum*. The section Trifoliata offers some excellent aesthetic qualities for possible use such as the very attractive defoliating bark of *A. griseum*. Excellent hardiness potential can be gained from using *A. mandshuricum*. *A. triflorum* also has much to offer in this group in both hardiness and aesthetic qualities. The transgressive segregation approach could also be useful with *A. rubrum* to incorporate greater drought tolerance and tolerance to higher soil pH.

I would like to give you a brief summary of our plant improvement research in Minnesota. For further information, our research was described in the August 15, 1983, issue of the American Nurseryman (8). Our primary goal is to develop and/or identify superior landscape plants adapted to our climate. We approach this through plant breeding activities and through testing of plant species and clones that we acquire from nurseries, other arboreta, and experiment stations worldwide. In this effort we are trying to acquire germplasm of species from areas of their native range most similar to our own. This past July, I had an opportunity to observe native plant materials in Northern China. We collected seed of a few species that were ripe at that time but, unfortunately, seed of most species was not. We are working on developing further cooperative efforts with our Chinese colleagues for exchange of seeds and with cold hardiness research.

Of our breeding activities, our most concentrated effort at present is development of cold-hardy deciduous azaleas. 'White Lights', 'Pink Lights', and 'Rosy Lights' have been introduced and will be available on the retail market this coming spring. 'Spicy Lights' will be officially introduced the following

spring. We hope to eventually introduce a number of additional clones to give a broad color range with reliable hardiness. We have a number of selections that we are currently evaluating in colors of yellow, various shades of orange, and bicolors. Our greatest need at present is true reds and we are making crosses to achieve that end.

Other current breeding activities and goals include:

1. Development of clones of *A. rubrum* and *Fraxinus americana* incorporating superior fall color and growth habit with reliable winter hardiness for Minnesota and areas of similar climate.

2. Crossing within the Lantana section of *Viburnum* to incorporate cold hardiness with superior aesthetic qualities of flower size, color and fragrance, leaf quality and plant form.

3. *Lonicera* resistant to the honeysuckle aphid with superior aesthetic and utilitarian qualities.

4. *Cornus sericea* with brighter stem color, good fall color, and leaf spot resistance.

5. Intergeneric hybridization between *Sorbus* and *Aronia*, or other members of the Pomoideae subfamily, to incorporate fireblight resistance and recombine other aesthetic qualities.

6. Hybridization of *Spiraea* to combine the dwarf plant habit of daphne spiraea with golden spring and fall foliage color of goldflame spiraea and, secondly, to obtain dwarf types with brighter flower colors.

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PLANT NOMENCLATURE AND NAMING NEW CULTIVARS

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To review how plant names are formulated, what makes a name legitimate, and why and how to register a cultivar name, let us follow an example. You are on a fishing trip. A storm comes up, the boat sinks, but you make it safely to a deserted island where there is no evidence that man has ever set foot before. While awaiting rescue, you discover some small trees that look very similar to *Hibiscus syriacus*, but the flowers and growth habit are different from any hibiscus that you know. Some specimens of this plant bear yellow flowers; others have finished flowering and have set seed. You gather seeds and specimens and, when rescued, you take your plant specimens with you.

Once safely at home, you try to determine the identity of the mystery plant by using keys in books such as Rehder's *Manual of Cultivated Trees and Shrubs*, but your specimens just do not fit the keys or descriptions. Having exhausted your own resources to identify the plant, you send it to a taxonomist at a local university. Some time later he informs you that your plant is indeed a *Hibiscus*, but that it appears to be a new species. He states that he will publish this information.

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BOTANICAL NAME FOR THE SPECIES

He suggests that the new species be named for a mutual friend, Al Fordham. Together you weigh the merits of calling it *Hibiscus fordhamii* (Fordham's hibiscus) or *Hibiscus fordhamianus* (Fordhamian hibiscus). You decide on *Hibiscus fordhamii*. The taxonomist, Frank Smith, publishes the proposed name and a description of the plant (in Latin) in a botanical journal. A pressed specimen is placed in a herbarium as the official representative of this new species.

Since the first name properly published with description becomes the legal name for a plant, this plant will be known henceforth as *Hibiscus fordhamii*. The name of a species is composed of two words, the genus name followed by a specific epithet. The publisher's name, abbreviated, is added as the author of this binomial. The full name of the plant is now: *Hibiscus fordhamii* F. Sm.

Correct Usage: The initial letter of the genus name is always capitalized. The specific epithet is *not* capitalized. In the past, the first letter of certain specific epithets was capitalized, but the recommended practice today is to keep all specific epithets lower case. The entire binomial is in italics, or each word underlined separately if italics are not available.

COMMON NAMES

Now, we skip ahead a few years. An article about the plant and how you discovered it has appeared in the pages of *Horticulture* magazine. The author of that article coined a common name, "island hibiscus," thinking that this name sounded more exciting than Fordham's hibiscus and would make more readable copy. Actually, there are no rules for common names. They vary with time, place, people, and language and therefore are unreliable for clear communication.

BOTANICAL VARIETIES

Among plants found in nature, variants below the species level may be classified as a subspecies (subsp. or ssp.) variety (var.) or form (f.). Subspecies are used in complex species where taxonomists feel necessary. They are occasionally encountered in horticulture, but more often we deal with varieties and forms. Here, we will describe varieties next and forms later.

A variety may be referred to as a botanical variety, natural variety, or *varietas*. It is a group of plants within a species characterized by variant traits which come true from seed and have a distinct geographic distribution.

Some of the plants of *Hibiscus fordhamii* which you discovered on the island had glabrous (hairless) leaves, while others, including the sample to which the name *Hibiscus fordhamii* was applied, had fuzzy, pubescent foliage. When seeds gathered from hairless plants are sowed, all of the seedlings are hairless, too. Since this variation comes true from seeds, plants with this trait should be considered a botanical variety and given a name to distinguished them from the typical species. Your taxonomist friend, Frank Smith, has retired, but another expert on *Hibiscus*, Martin Andrews, gives the name var. *glabrescens (Hibiscus fordhamii* var. *glabrescens)* and publishes this information. With the names of the authors included, the full name of the variety is *Hibiscus fordhamii* F. Sm. var. *glabrescens* M. Andr.

Since a variant has been named at the level of a botanic variety, a name at the same level automatically is given to the original plants (the typical species). This is done by repeating the specific epithet as the variety name: *Hibiscus fordhamii* var. *fordhamii*. Ordinarily, this variety name would be used only when necessary to distinguish between the two types.

Correct Usage: Note that names of botanical varieties are in Latin, italicized or underlined, and follow the name of the species with the abbreviation "var." between the specific epithet and the variety name.

AN INTERSPECIFIC HYBRID

You attempt to hybridize island hibiscus with shrub althea and succeed in creating large shrubs with yellow flowers during the summer months, a color not seen in shrub altheas *(Hibiscus syriacus)*. The only name the hybrid plant has at this point is a formula showing its parentage: *Hibiscus fordhamii* × *H. syriacus*. These plants create a mild sensation. You decide that a hybrid with such "potential," commercially, should have its own specific epithet. You dub it *Hibiscus* ×*superbus*, and the taxonomist, Martin Andrews, concurs and agrees to publish this name.

Correct Usage: The name of a hybrid derived from crossing different species has a multiplication sign between the genus name and the specific epithet to indicate that the plant is an interspecific hybrid. (When the multiplication sign is distinctively different from letters, it should immediately precede the specific epithet; when the letter x is used for the multiplication sign, the name will be more readable if a space separates it from the epithet.)

CULTIVARS

A cultivar (cultivated variety) is a group of plants with some trait(s) valued by mankind and maintained in cultivation by mankind's efforts. Cultivars may be propagated asexually or by seed lines that give uniform offspring, such as inbred lines, or F_1 hybrids. Woody cultivars are usually asexually propagated, while among vegetables and annual garden flowers, seed-grown cultivars are common.

One day a mutation appears on a plant of *Hibiscus* × *superbus* — a branch with yellow variegated leaves. Here is a novelty that might sell well. You propagate it from cuttings to preserve the variegation and decide to give the resulting plants a cultivar name. Should you use a name like 'Areomarginatus'? Absolutely not! Cultivars named *before* the start of 1959 may be (and often are) in Latin, but names given to cultivars from January 1, 1959, onward, must be in a modern language.

You like the name 'Golden Glow'. However, to make sure that this name has not been used previously, you contact the Registrar for *Hibiscus* cultivar names, requesting a list of cultivar names already in use in the genus *Hibiscus*. When the list arrives, you note that the name 'Golden Glow' is distinctive and not confusable with any name already given to this group of plants, so you decide to "go" with it.

Correct Usage: Names of cultivars are *not* italicized or underlined. Each word in a cultivar name is capitalized, and the name is distinguished by being set apart from the species name or common name by single quotation marks or the abbreviation, "cv." For this cultivar, the name could be written *Hibiscus* ×*superbus* 'Golden Glow,' *Hibiscus* ×*superbus* cv. 'Golden Glow,' or hibiscus cv. Golden Glow.

If the hybrid hibiscus had not been given its own specific epithet and still were known by the formula *H. fordhamii* × *H. syriacus*, the cultivar name would be used directly following that of the genus: *Hibiscus* 'Golden Glow.'

OTHER CULTIVARS

Another cultivar arises, not as a budsport, but as a botanical form. A form *(forma)* is composed of plants within a species with a minor variant trait which occurs occasionally or sporadically and seldom comes true from seed. In our case, orange flowers occasionally occur on island hibiscus. The taxonomist has named this form *Hibiscus fordhamii* f. *aurantiacus*.

You select a specimen of this form with compact growth habit and especially large flowers for propagation from cuttings. You decide to call this clone 'Harvest Moon.' Upon

checking with the Registrar for *Hibiscus*, you find that this name is acceptable. The full name of the cultivar is *Hibiscus fordhamii* f. *aurantiacus* 'Harvest Moon,' but in usage it may be shortened to *Hibiscus fordhamii* 'Harvest Moon' ('Harvest Moon' island hibiscus).

You submit the necessary information to the Registration Authority so that the cultivar names 'Golden Glow' and 'Harvest Moon' will be officially registered and included in their checklist of cultivar names. In addition to the names and descriptions of the cultivars, the Registrar requests certain information and perhaps photographs or herbarium specimens. To make your task easier, he supplies short forms for you to fill out with the necessary facts.

A third cultivar is selected from the glabrous variety: *Hibiscus fordhamii* var. *glabrescens* 'Daydream.' Note that the name of a cultivar selected from a botanical variety follows the varietal name.

A NECESSARY NAME CHANGE

Name changes may occur for several reasons.

1. Plants in cultivation have been misidentified. When the error is found, these plants will have to be re-labeled.

2. The same name has been applied to more than one plant. The first plant so named retains the name; others must be renamed.

3. An older, valid name is discovered for a plant already known by another name. The older name has priority, with the exception of certain genus names which have been conserved.

4. Scientific evidence requires redefining the limits of a group of plants, so that some members may be shifted to another category.

5. Different opinions exist among botanists as to the proper limits of a group of plants. In such a case, the horticultural community will have to decide which botanist to follow.

The taxonomist, Martin Andrews, has come across an article written in the Finnish language in 1890, about some plants discovered earlier and named by a Finnish plant explorer, Eero Helperin. The article describes one plant that appears to fit the description of *Hibiscus fordhamii*. Helperin had named it *Hibiscus magnificus*. Even though the plant was never brought into cultivation, it was adequately described in Latin, and a herbarium specimen has been located in a Finnish museum herbarium.

Taxonomists compare your plant with this specimen and determine that they are the same species. The older name has priority and takes precedence over the name you gave this species. A plant has one — and only one — current, correct, worldwide name, in this case, *Hibiscus magnificus*. The name you gave it is reduced to a botanical synonym — an out-of-date name. It can be listed in parentheses after the correct name so that people will recognize that the newly *found* name refers to the plant that you brought into cultivation and helped to popularize: *Hibiscus magnificus* Helperin (*H. fordhamii* F. Sm.).

RULES OF NOMENCLATURE

Guidelines for botanical names are in the *International Code of Botanic Nomenclature*. Of more importance to horticulture is the "Cultivated Code," the *International Code of Nomenclature for Cultivated Plants — 1980* (Regnum Vegetabile Volume 104). This booklet includes rules and recommendations for forming cultivar names and determining the legitimacy of a name.

Articles 1 and 3 of the Cultivated Code state that cultivated plants are essential to civilization, and it is important, therefore, that a precise, stable, and internationally accepted system should be available for their naming. The aim of the Cultivated Code is to promote uniformity, accuracy, and fixity in the naming of agricultural, horticultural, and silvicultural cultivars.

The use of common names and trademarks are *not* regulated by the Code.

Who can name a cultivar? Any person may name a cultivar so long as it has not been legitimately named previously, and if it is not against the expressed wish of the cultivar originator or his assignee.

Can an older name be re-used if the plant has disappeared? A name may not be reused later for any other cultivar on the assumption that the original cultivar no longer exists. However, Registration authorities have the power to grant exceptions to this rule under certain specified conditions.

What makes a name legitimate? A legitimate name must be: 1. selected in accordance with the Cultivated Code; 2. published in a manner stipulated by the Cultivated Code (explanation follows); 3. applied to a cultivar not already legitimately named; 4. a name which does not duplicate a name already in use for another cultivar of the same cultivar class.

"Cultivar class" means the taxonomic level within which the use of a cultivar name for two distinct cultivars would lead to confusion. For example, the existence of the cultivar named 'Harvest Moon' among rhododendrons prevents the use of this name for an azalea cultivar, but does not prevent using 'Harvest Moon' as the name of a peony cultivar.

What are the requirements for valid publication?

1. The name must appear in printed or similarly duplicated reading matter which is distributed or available to the public. Non-technical newspapers and handwritten materials, even if reproduced by mechanical or graphic processes, are *excluded*.
2. The reading material must be clearly dated at least as to year.
3. Publication of the cultivar name must be accompanied by a description of the cultivar or by a reference to a previously published description. The description should contain particulars to distinguish the cultivar from related cultivars, whenever possible. Parentage and history of the cultivar and the name of the originator or introducer should be included, if known.
4. Whenever possible, an illustration should be provided with the description, and a pressed or otherwise preserved specimen should be deposited in a public herbarium, such as at the U.S. National Arboretum, 3501 New York Avenue NE, Washington, DC.

Examples of valid publication are the printing of the cultivar name accompanied with description (and illustration, if possible) in a dated trade catalog, horticultural journal or magazine, or registration list of a Registration Authority.

REGISTRATION AUTHORITIES

To administer the Code, cultivar Registration Authorities have been appointed. These are national or international agencies entrusted with compiling and publishing lists of cultivar names within a particular genus or cultivar class. They also establish which names are valid and legitimate and which are clearly synonymous; they advise on and accept new names; and they interpret the Code in certain instances. The main objective of registration is to stabilize and standardize the nomenclature of cultivated plants.

Registration is one way to ensure that names are the legitimate names for these cultivars and that no other plants may use these cultivar names. The name of every new cultivar should be registered with the appropriate Registration Author-

ity. Cultivar registration is simply the acceptance of a cultivar name by a Registration Authority and the inclusion of this name in a register. This process helps to avoid violating one or more of the rules and recommendations for cultivated plant nomenclature. It also helps to distinguish cultivar names from common and botanical names and ranks.

Registration is for the *name only*. Acceptance of a name for cultivar registration does *not* imply judgement on the distinctiveness or merit of the cultivar.

Examples of organizations which may act as Registration Authorities are plant societies, such as the Holly Society of America, Inc., or botanic gardens, arboreta, or research institutions, such as the Arnold Arboretum and the U.S. National Arboretum. The U.S. National Arboretum acts as Registration Authority for those genera of woody plants for which separate registration authorities do not exist. Information on Registration Authorities for various genera, and their addresses, may be obtained from Mr. F. Vrugtman, Vice-Chairman, ISHA Commission for Horticultural Nomenclature and Registration (address: Royal Botanical Gardens, Box 399, Hamilton, Ontario, Canada L8N 3H8), or from the American Association of Nurserymen.

In conclusion, the Codes of Nomenclature and Cultivar Name Registration have been designed to stabilize plant names and bring order out of a chaotic situation. We are presently in a transitional phase, sorting out what is right and wrong. By using correct names to the best of our ability, we who deal with aesthetically and economically important plants will speed up the process and arrive sooner at a point of stability.

NEW PLANT FORUM

JACK ALEXANDER AND GARY KOLLER, Moderators

MODERATOR ALEXANDER: Darrel Apps from Longwood Gardens will begin the new plants session with a presentation on the J. Franklin Styer Award of Garden Merit and then discuss a promising plant.

DARREL APPS: The Pennsylvania Horticultural Society established the J. Franklin Styer Award in 1980. Its purpose is to promote the recognition and dissemination of woody ornamental plants of outstanding garden merit. Any person or organization may submit a plant or plants. However, award is made to the plant and not the introducer. Entries must be

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Registration is for the *name only*. Acceptance of a name for cultivar registration does *not* imply judgement on the distinctiveness or merit of the cultivar.

Examples of organizations which may act as Registration Authorities are plant societies, such as the Holly Society of America, Inc., or botanic gardens, arboreta, or research institutions, such as the Arnold Arboretum and the U.S. National Arboretum. The U.S. National Arboretum acts as Registration Authority for those genera of woody plants for which separate registration authorities do not exist. Information on Registration Authorities for various genera, and their addresses, may be obtained from Mr. F. Vrugtman, Vice-Chairman, ISHA Commission for Horticultural Nomenclature and Registration (address: Royal Botanical Gardens, Box 399, Hamilton, Ontario, Canada L8N 3H8), or from the American Association of Nurserymen.

In conclusion, the Codes of Nomenclature and Cultivar Name Registration have been designed to stabilize plant names and bring order out of a chaotic situation. We are presently in a transitional phase, sorting out what is right and wrong. By using correct names to the best of our ability, we who deal with aesthetically and economically important plants will speed up the process and arrive sooner at a point of stability.

NEW PLANT FORUM

JACK ALEXANDER AND GARY KOLLER, Moderators

MODERATOR ALEXANDER: Darrel Apps from Longwood Gardens will begin the new plants session with a presentation on the J. Franklin Styer Award of Garden Merit and then discuss a promising plant.

DARREL APPS: The Pennsylvania Horticultural Society established the J. Franklin Styer Award in 1980. Its purpose is to promote the recognition and dissemination of woody ornamental plants of outstanding garden merit. Any person or organization may submit a plant or plants. However, award is made to the plant and not the introducer. Entries must be

received by December 1 for examination in February of the next year. Application forms are available from:

J. Franklin Styer Award
Pennsylvania Horticultural Society
325 Walnut Street
Philadelphia, PA 19106
For further information call 215-625-8250

The award is given in two stages:

The first stage is the Certificate of Preliminary Commendation. A group of horticulturists and landscape architects reviews entries each February. The committee makes its selections on the basis of slides and written descriptions.

The second stage is the J. Franklin Styer Award itself. After receiving the Certificate of Preliminary Commendation, plants become eligible. The applicant is required to distribute a number of plants for testing among evaluators in the mid-Atlantic States. The length of the test depends on the nature of the plant. Before final consideration for the J. Franklin Styer Award the plant must have a registered cultivar name and must be propagated for distribution. Plants eligible for awards from associations and plant societies (such as hybrid tea roses) are not eligible for either phase of the J. Franklin Styer Award.

The J. Franklin Styer Award has not been granted to date. Plants that have received the Certificate of Preliminary Commendation and are currently being tested are:

1981

Magnolia 'Elizabeth'
Kalmia latifolia forma *myrtifolia* (seedling)
Prunus 'Okame'
Cornus kousa 'Elizabeth Lustgarten'
Pyracantha coccinea 'Rutgers'

1982

Ilex serrata × *I. verticillata* 'Sparkleberry'
Malus 'Jewelberry'
Viburnum, nudum 'Winterthur'

1983

Ilex serrata × *I. verticillata* 'Autumn Gold'
Ilex serrata × *I. verticillata* 'Harvest Red'
Pieris japonica 'Crystal'
Rhus chinensis 'September Beauty'
Viburnum 'Eskimo'
Cornus kousa 'Square Dance'

Sedum hybridum cv. Weihenstephaner Gold. Longwood Gardens originally acquired *Sedum hybridum* cv. Weihenstephaner Gold in 1976 from England under the name *S. floriferum* cv. Weihenstephaner Gold. Dr. Donald G. Huttleston, Longwood taxonomist, later identified it as a *S. hybridum* cultivar.

Dr. Huttleston described it as follows: "Dense ground cover about 4 in. deep; leaves glabrous, grayish green, flattened, concave above, oblanceolate, to about 1 in long by ⅓ in wide with 2 or 3 pairs of prominent teeth on upper third, forming rosettes toward ends of sterile shoots; flowers ½ in in diameter, bright yellow, in flat-topped clusters to 2 in in diameter; ovaries turning orange-red after flowering."

The normally gray-green leaves turn purplish late in the fall and during the winter. In full sun yellow star-shaped flowers appear 2 in above the foliage in mid-May and continue until around the beginning of July. About the first of June small orange-red fruit capsules appear and remain attractive until the end of July. Plants are extremely hardy and have overwintered in containers above the ground in southeastern Pennsylvania (USDA Zone 7a).

Cuttings for propagation can be obtained from Dr. Robert Armstrong, Longwood Gardens, Kennett Square, PA 19348.

MODERATOR ALEXANDER: Bill Thomas from Longwood Gardens has an herbaceous perennial to present.

BILL THOMAS: *Hemerocallis* 'Stella de Oro', bred by Walter Jablonski of Merrillville, Indiana, and registered in 1976, is a unique daylily because of its long season of bloom. First blossoms appear about June 10 at Longwood Gardens in southeastern Pennsylvania and subsequent scapes continue to produce flowers until heavy frosts cut them down in late October. Although the individual gold flowers are less than 3 in. across, multiple scapes provide a mound of color. Heaviest bloom is from about June 10 to 25 followed by a slight pause of 3 to 4 weeks. From that point on 'Stella de Oro' blooms continuously until fall. It produces many new fans and needs to be divided every 3 years.

Well-grown plants are about 18 in tall when in flower. The foliage is narrower and more grass-like than that of large cultivars. Unlike many daylilies the flowers open at night (by 10 pm and stay open for about 24 hrs giving two sets of flowers for an evening display. The plant is completely dormant in winter and dies to the ground by the end of November. 'Stella de Oro' is also unique in that its blossoms open well during cool nights.

Propagation material can be purchased from nurseries specializing in daylilies.

MODERATOR ALEXANDER: Paul Meyer has one plant to show us.

PAUL MEYER: In the mid-1930's Dr. Henry Skinner brought to the United States a rooted cutting of a hybrid cherry which had attracted his attention in England. It was collected in the garden of Captain Collingwood Ingram, the famed cherry collector and hybridizer. Over the years, this cherry, 'Okame', has become one of the most popular flowering trees at the Morris Arboretum.

'Okame', a hybrid of *Prunus incisa* and *P. campanulata*, is covered with clusters of clear carmine-pink flowers each spring. In Philadelphia, it has come into full bloom as early as March 28 and as late as April 13. Its bloom usually preceeds *P. subhirtella* by 5 to 7 days. Full bloom usually lasts 7 days. The flower buds are deep maroon and after petal drop the red calyx

and stamens persist for another week. Thus, spring color lasts up to 3 weeks.

'Okame' forms a small upright tree maturing at about 25 feet. Its small stature and fine twig and leaf texture make it adaptable to the small garden. In the autumn its foliage colors to bright shades of orange and yellow.

'Okame' cherry is still rare in the nursery trade but seems readily adaptable to field or container production. It roots readily from softwood cuttings. At the Morris Arboretum 6-in cuttings are taken in mid to late June. These are treated with Hormo-root A (1000 ppm IBA and Thiram); 95% of the cuttings are well rooted within 4 weeks. Terminal cuttings result in plants with the best upright form; lateral cuttings require pruning to form a strong leader.

As a young plant, it grows rapidly and usually begins flowering immediately. It is fully hardy in Philadelphia and the flower buds withstand late spring frosts. The Arnold Arboretum reports that it thrives in Boston and a specimen observed in Cincinnati for the past 5 years has been unaffected by the cold winters.

A limited number of rooted cuttings are available from the Morris Arboretum for introduction to commercial nurseries.

MODERATOR ALEXANDER: Peter Vermeulen will next present two plants.

PETER VERMEULEN: *Juniperus virginiana* 'Sparkling Skyrocket' is a sport of 'Skyrocket'. 'Sparkling Skyrocket' is distinctly and liberally highlighted by dibs and dabs of amber among a slim and slender but dense column of silvery blue-gray foliage. The striking impression of this rapid growing plant makes it easy to imagine a skyward bound sentinal rocket. *Juniperus virginiana* 'Sparkling Skyrocket' is easily propagated by softwood or hardwood cuttings in a sand, or sand and peat medium. It can also be grafted on *J. chinensis* 'Hetzii'. It originated in our nursery.

Picea pungens 'Royal Knight' develops into uniform compact pyramids of nice colonial blue. 'Royal Knight' grafts well on *Picea abies* in January and February. The J.C. Bakker and Sons Nursery selected this plant about 25 years ago from a batch of predominantly blue seedlings.

MODERATOR ALEXANDER: Dave Bakker is next with one plant.

DAVE BAKKER: *Spiraea* 'Gold Mound' is a natural cross of *Spiraea* 'Gold Flame' × *S. nipponica*. It was selected by Mr. Huber of W.H. Perron, Boulevard LaBelle, Chomedy, Montreal, Quebec. The gold leaves remain a fresh yellow in sunny or shady locations. 'Gold Mound' forms a medium-sized shrub maturing to between 12 and 24 in. and is hardy to −30°F. Flowers are light pink but the yellow foliage dominates.

MODERATOR ALEXANDER: Peter Del Tredici has one plant to present.

PETER DEL TREDICI: This evergreen clone of the sweet bay magnolia is growing on an exposed site in the front yard of a private home in Milton, Massachusetts. Nothing is known of its history except that it was planted around 1955 by the Blue View Nursery of Canton, Massachusetts. The tree has been under observation by Arnold Arboretum staff members since 1977. During this time, it has been exposed to a low temperature of −10°F and retained its leaves in a fresh green condition. According to the tree's owner, the plant has never shown any winter damage.

While *M. virginiana* is typically evergreen in the deep south, it is deciduous in the north. Seedlings of evergreen trees, when grown in the north, are usually either winter-killed or deciduous. *M. virginiana* 'Milton', therefore, is unusual in that it holds its leaves until well after the appearance of the new leaves in spring.

The plant produces fragrant, eight petaled flowers over a two-month period in July and August. Nearly every blossom on the tree sets a fruit that contains viable seed. It sets seed in the absence of any other specimen of *M. virginiana* in the vicinity.

'Milton' is about 30 ft tall with a strongly upright habit that is atypical of sweet bay magnolias grown in the north. The leaves are also distinctive, being long and narrow. They range in size from 4 to 6 in long and 1 to 1½ in wide. 'Milton' is different from another evergreen selection of *M. virginiana*, 'Henry Hicks', by virtue of its leaf shape and the fact that it is highly self fertile.

I have had seedlings of 'Milton' under observation at the Arnold Arboretum for 3 years. They are straight stemmed, between 1 and 2 ft tall, and fully evergreen. They also have narrow leaves like the parent. It is normal for all sweet bay magnolias to be evergreen when young. However, I feel that the self fertility of the tree, coupled with its isolation, makes it likely that seedlings will be similar to the parent. Scion wood for grafting is available from the Arnold Arboretum. Illustrations of 'Milton' magnolia have been published in *Arnoldia* 41(2):36-49. 1981.

MODERATOR ALEXANDER: Kris Bachtell has one plant to show us.

KRIS BACHTELL: *Sibiraea laevigata* (Altai spirea) is a hardy, slow growing, dwarf shrub with several ornamental attributes. Its attractive foliage, spring flower display, and showy fruits, along with its freedom from diseases and insect pests suggest that it has a use in today's landscape and nursery trade.

Despite its common name, Altai spirea, this plant does not belong to the genus *Spiraea* as was once thought, but is placed in the genus *Sibiraea*. As its generic name implies, it is native to Siberia. Our plant at the Morton Arboretum showed no winter damage after −27°F during the winter of 1981-82.

Our 21 year old cutting-produced specimen is now only 24 in tall with a spread of 4 ft. It has been growing in full sun and a rather heavy clay soil. This summer the foliage remained in excellent condition despite the excessive heat and uneven distribution of rain.

The plant's texture is rather coarse with stout stems suckering from its interior. Adding to this coarseness are the oblong, glaucous leaves. Their color is a beautiful blue-green throughout the spring and summer. Fall coloration is not significant.

Sibiraea laevigata begins to flower in early May. Its small, ⅛ in white flowers are borne on 4 to 5 in panicles and are evenly distributed throughout the plant. The flowering period lasts approximately 3 weeks. After flowering, clusters of small fruits start to develop and turn a bright yellow color. From a distance it actually appears as if the plant is flowering. In late July, the fruits assume a golden color. Finally, in late August-early September, the clusters turn brown and persist on the plant through most of the winter.

Sibiraea laevigata can be propagated by either seeds or cuttings. Seed germination is easy, requiring no stratification. We stored the seed cool and

dry until sown in mid-March. With cuttings taken in early July, we've had 50% success when treated with 2000 ppm IBA in a quick-dip solution.

If you are interested in obtaining a plant for trial purposes, please contact me at the Morton Arboretum. We plan to distribute approximately 300 seedlings in October, 1984.

MODERATOR ALEXANDER: Our next speaker is Barry Yinger.

BARRY YINGER: Correspondence relating to my two plants should be sent to Carl R. Hahn, Maryland-National Capital Park and Planning Commission, 8787 Georgia Ave., Silver Springs, MD 20907.

Cornus kousa 'Gold Star' was introduced in 1977 by the Sakata Nursery Company, Yokohama, Japan.

On this plant the leaves are dark green, with an irregular central blotch of deep butter-yellow covering one-third of the leaf area. On new growth the blotch is chartreuse. The form of the plant and flower characters are typical of the species. This vigorous cultivar is at its best in full sun and beautiful in all seasons.

Cornus kousa 'Snowboy' was introduced in 1977 by the Sakata Nursery Company.

The leaves of this selection are pale gray-green with a regular white margin, 2 to 5 mm wide, which occasionally invades the center of the leaf. Splashes of yellow-green, or small areas of paler gray-green along the edge of areas of darker gray-green, occur infrequently. Axillary tufts of hair are absent on the leaf undersurfaces. The leaf apices are often reddish, as well as the leaf bases on new shoots and young twigs. Flowers and habit are typical of the species. This plant sunburns in late summer in our climate unless grown under high shade or on the north side of a building.

MODERATOR ALEXANDER: David Beattie has two plants to show us.

DAVID BEATTIE: *Prinsepia sinensis*, or cherry prinsepia, is a member of the Rosaceae family. It is a spiny deciduous shrub that grows to about 8 ft and is native to northern China and Manchuria. Prinsepia tolerates very low temperatures and survives as far north as Morden, Manitoba, Canada.

Prinsepia flowers just before Forsythia 'Lynwood Gold.' Flowers are born in clusters at each node and are cream colored about ½ in across. Fruit is somewhat smaller than, but similar in color and shape to a sour cherry. Fruit set is not always reliable either because of self incompatibility, or because flowering occurs so early that insect pollinators are unavailable. The drupe fruit has a heavily fissured stone that has been used in bead art.

Propagation of prinsepia is by seed or softwood cuttings. When propagated by seed the shoot must be chilled after germination to bring about normal shoot elongation. Softwood shoots root easily if taken before growth hardens and terminates in early July. Thereafter, cutting propagation is extremely difficult.

Because of its dense growth habit prinsepia has been used as an ornamental hedge plant or for wildlife cover. One of its greatest assets is that it is one of the first shrubs to "green up" in the spring — even before bush honeysuckle.

Although prinsepia has many uses, it is unavailable in the nursery trade and must be obtained from arboreta or botanical gardens.

Eustoma grandflorum, or prairie gentian, is sometimes referred to as *Lisianthus russellianum*. It is a member of the gentian family and is native to the western part of the U.S. Great Plains, from Texas to Nebraska. This little known herbaceous perennial grows to about 3 ft high. Flower colors include blue, white, and pink. When grown out-of-doors in the 1983 Pennsylvania State University Trial Gardens, plants began blooming in July and continued until frost. Flowers are 2 in across, showy, and the continuous formation of new buds on upright stems ensures a continual floral display. Annual flowering selections have been introduced for bedding plant use and as flowering pot plants. Although winter hardy as far north as Nebraska, overwintering depends on the formation of small rosettes at the base of the stem in the fall. Annual flowering forms were selected from plants in the southern part of its native range and may not form rosettes reliably. If this plant is to be grown as a hardy herbaceous perennial in the eastern U.S., selections from the northern portion of its range should be grown.

Color clones of *Lisianthus* can be propagated by dividing basal rosettes in the spring. However, seed propagation would be more economical. Seeds germinate in about 20 days at 70°F. but grow very slowly at first. Therefore, care should be taken not to overwater young seedlings.

MODERATOR ALEXANDER: Harrison Flint has five plants to tell us about.

HARRISON FLINT: *Firmiana simplex* (Chinese parasol tree, Japanese varnish tree, Phoenix tree) is a temperate-zone member of the mostly tropical Sterculia family (Sterculiaceae) is useful at least from USDA Plant Hardiness Zone 7b (Washington, DC, Nashville, and Memphis, Tennessee) southward. Its most striking landscape features are its strongly whorled branching and smooth, pale-green bark. The palmately-lobed leaves are covered with a rusty tomentum as they unfold, then glabrous at full expansion. Small, white flowers, in upright clusters to 20 in long add interest in midsummer. Maintenance needs are minimal.

Kalopanax pictus (castor aralia), a member of the aralia family (Araliaceae) is a useful and interesting shade tree from USDA Zone 5a (southern Vermont to southern Wisconsin) southward at least to Zone 8a (Atlanta, Georgia). Like other members of the family, this tree is covered with large, sharp prickles, which must be removed from the trunk and lower branches for safety of children. The large, palmately-lobed leaves, reminiscent of those of castor-bean (hence the common name) lend a "tropical" appearance, and usually turn dull reddish before falling in mid-autumn. Large compound umbels of small white flowers in mid-summer are followed, in early autumn, by quantities of small, shiny black fruits, which are usually taken quickly by birds. This trouble-free tree appears sparse, even stark, in winter, but is unusually interesting during the leafy season.

Styrax americanus (American snowbell) is a large, graceful shrub, or very small tree, native to the southeastern U.S. It is seldom encountered in landscape use, but is a handsome flowering plant useful in a wild garden, mixed shrub border, or even trained as a tiny patio tree. Its useful limits range northward at least through USDA Zone 7b, and probably to Zone 6b as well.

Styrax obassia (fragrant snowbell) is a small Japanese tree less common than its relative, S. *japonicus*, yet worthy of a place in landscapes in Zones 6b to 8b, at least. Unlike S. *japonicus*, its fragrant flowers are borne in pendulous racemes, 4 to 8 in long. These are partly hidden by the large,

rounded leaves, but this is a minor objection. A major functional advantage of *S. obassia* is that it is upright and fairly narrow in form, while *S. japonicus* is so wide-spreading that it cannot be used where lateral space is at a premium.

Pterostyrax corymbosus (shrubby epaulette tree) is a handsome member of the styrax family (Styracaceae), usually not exceeding 15 to 20 ft in height. It has been de-emphasized in favor of its larger relative, *P. hispidus*, because of its smaller flower clusters, 4 to 5 in. long, and presumed lesser cold-hardiness. However, fine specimens can be seen in Louisville, Kentucky, in USDA Zone 6b (perhaps more like 7a in the microclimate afforded by the city and adjacent Ohio River), so any difference in cold-hardiness between these species must be small. On balance, *P. corymbosus* is a useful, smaller version of *P. hispidus*, with its own landscape function. Both species are Asian in origin, and both have been trouble-free in limited usage.

MODERATOR ALEXANDER: I have a small tree to present.

JOHN ALEXANDER: *Symplocos paniculata* is a large shrub or small tree native to the Himalayas, China, Korea and Japan.. It was introduced to cultivation in 1875. Several specimens in the Arnold Arboretum date to 1897 and the largest of these is perhaps 6 m tall with a spread of about 10 m.

In late May or early June, just after peak lilac bloom, it produces an abundance of fragrant white flowers in both terminal and axillary panicles. It is reported by Michael Dirr to be flower-bud hardy to −25°F. Plants are relatively self-sterile and may not produce an abundance of fruit unless several different individuals are planted in one area.

Although it is principally grown for its bright blue fruit, both black and white fruited forms have been reported. The fruit, a single seeded drupe, is very attractive to birds. The blue color gives this species one of its common names "sapphireberry."

Propagation by softwood cuttings under mist can be very successful. One experiment at the Arnold Arboretum yielded 100% in all variables; even the control lots rooted. These were evaluated and potted after rooting, but the following spring not a single cutting grew out. However, we have been successful by rooting them in flats from which they are not transplanted until growth commences in spring.

When a very attractive plant is rare to horticulture, there is usually a good reason. Often the reason is that somewhere along its path of production it is difficult for the nurseryman to handle. *Symplocos paniculata* has such a reputation. Propagation by seed can be very difficult. The seed, when ripe, contains a fully formed embryo, which requires two years for it to germinate. A relatively long period of warm stratification is required to induce radicle emergence, and that must be followed by approximately 3 months cold stratification. Testing combinations of stratification, scarification, and gibberellic acid, Peter Del Tredici at the Arnold Arboretum showed that none of these treatments gave good results.

MODERATOR KOLLER: James Will has five plants to show us.

JAMES WILL: *Fontanesia fortunei* 'Titan' is a member of the Oleacae family. It has simple, obovate, entire leaves of 2 to 3 cm which are grey-green on the upper side and white on the underside. The flowers and fruits of this cultivar are inconspicuous, like the species.

'Titan' was named by the Cole Nursery Company because of its upright form. 'Titan' propagates very easily from both softwood and hardwood cuttings, and transplants well bareroot. This plant will grow well in many soil types and can withstand sun and semi-shade. Shearing during dormancy and mid-summer is necessary to keep 'Titan' in a desirable, densely-branched form. The species is hardy in southern Wisconsin (Zone 5a, USDA); 'Titan' should not differ in cold hardiness.

Fontaneisa fortunei 'Titan' can be seen at the Holden Arboretum of Mentor, Ohio. Presently, 'Titan' is propagated and grown by two nurseries: *Herman Losely & Son of Perry, Ohio, and Ned's Nursery of Circleville,* Ohio.

Hydrangea paniculata 'Tardiva' is the little-known, late-flowering form of the panicle hydrangea. In Lake County, Ohio, 'Tardiva' begins blooming in mid- to late August and remains showy through mid-September. The clone is finer textured than the popular 'Grandiflora'. The winter hardiness of this clone is similar to other *Hydrangea paniculata* clones (USDA 4a to 8a). 'Tardiva' roots easily both from hardwood and softwood cuttings. At Herman Losely & Son, hardwood cuttings are taken in December, treated with 20,000 ppm IBA and stuck in unheated sand benches. A 90% rooting success rate is common with this clone.

A large speciman of *H. paniculata* 'Tardiva' can be seen at Dawes Arboretum, Newark, Ohio. Many other arboreta exhibit this clone, including the Longenecker Horticultural Gardens of the University of Wisconsin Arboretum. This plant is presently propagated by a few nurseries, including Herman Losely & Son of Perry, Ohio, and Bobtown Nursery of Onacock, Virginia.

Mahonia aquifolium 'King's Ransom' is a vigorously growing, upright form. This clone was named by Mr. Harvey Templeton of Huntland, Tennessee over 20 years ago. 'King's Ransom' has red-bronze new foliage which remains colorful for 3 months after emergence. For the rest of the season, the foliage is dark bluish-green with the appearance of a matte finish. The flowers are larger than in the species and are borne in mid-May. The berries appear in late June and are a glaucous bright purple. Through informal reports, it appears that 'King's Ransom' suffers from winter foliage burn less frequently than seed-grown mahonias.

Mahonias can easily be asexually propagated by cuttings taken in late November and stuck in heated sand benches. Cloromone treatments are effective, as well as 20,000 ppm IBA in talc. 'King's Ransom' is especially useful as a container plant because of its uniform rate of growth and exceptional upright form. It is equally well suited for field growing.

'King's Ransom' is not widely distributed. The Longenecker Horticultural Gardens of the University of Wisconsin is testing this plant for winter hardiness in zone 5a (USDA). Few commercial sources exist for 'King's Ransom'.

Rhamnus frangula 'Asplenifolia' is a strap-leaved variant of the alder buckthorn. 'Asplenifolia' was first mentioned in an 1888 Morton Arboretum publication. The clone has leaves as long as in the species, but only ½ cm in width. 'Asplenifolia' is a slow growing upright shrub eventually reaching 2 m. Similar to the other selections of *R. frangula*, 'Asplenifolia' is hardy from Zones 4b to 8a (USDA). As with other *Rhamnus* selections, 'Asplenifolia' is easily rooted from softwood cuttings taken in mid-June. At Herman Losely & Son, 20,000 ppm IBA is used in talc and the cuttings are stuck in outdoor mist frames. The cuttings are left in the frames for 22 months.

Rhamnus frangula 'Asplenifolia' can be seen in many arboreta throughout the temperate region of the country. Propagation material is readily available from many commercial sources.

Rhododendron × 'Pink Plush' is an advanced generation natural hybrid of *R. bakeri* and *R. arborescens* selected and registered by Dr. David G. Leach. Dr. Leach selected this azalea while at Brookville Pennsylvania. During this time the plant was exposed to −28°F. without loss of buds or twig die-back. 'Pink Plush' has a vivid, clear pink flower and blooms in early June. The small flowers bloom in sequence and cover the plant until the 1st of July. The leaves are dark olive-green and are similar in size to *R. arborescens*, one of its parents.

'Pink Plush' can be propagated asexually like other deciduous azaleas. At Herman Losely & Son, best success has been with micropropagation. The azalea grows and multiplies well in culture, and will root and grow-on without difficulty.

'Pink Plush' is one of the eight North Madison azaleas selected by Dr. Leach. Propagules of this clone are available from Herman Losely & Son of Perry, Ohio, as well as Bovee Nursery of Oregon.

MODERATOR KOLLER: Dixon P. Hoogendoorn will present the next plant.

DIXON HOOGENDOORN: *Ilex verticillata* 'Compacta' has a dwarf growth habit and is more compact than most of the other *I. verticillata* cultivars. It may reach a height of 3 to 4 ft after many years. The cultivar was also named *I. verticillata* 'Red Sprite' a few years ago. *Ilex verticillata* 'Nana' is believed to be the same plant as well.

I presented this plant at the 1979 IPPS Eastern Region meeting in St. Louis, Missouri, and implied it was self-pollinating. *I stand corrected!* An occasional male is needed to facilitate pollination. This plant is a heavy fruiter and the large, bright, red fruit is magnificent and long lasting.

Ilex verticillata 'Compacta' can be used as an individual plant in foundation plantings, shrub borders, and is probably used most effectively in mass plantings. This cultivar would also seem to be a natural plant for garden centers to market during the fall or holiday season. It can be propagated with little difficulty by softwood cuttings taken in June.

MODERATOR KOLLER: Tom Tracz has three low-growing shrubs to present.

TOM TRACZ: *Rhus aromatica* 'Grow-Low' is a selection made for its low, spreading habit. Mature plants grow to a height of 30 in with a spread of 10 ft or more. 'Grow-Low', hardy to Zone 3, has a fast growth rate, is easily transplanted, and grows well in full sun or partial shade. The bright green foliage remains clean and insect-free during the summer, turning an orange-red in the fall. It is easily propagated in June or July when treated with 1000 ppm IBA.

Ribes alpinum 'Green Mound' was selected for its dwarf, compact form and resistance to leaf diseases. 'Green Mound', a male clone, does well in full sun or shade, growing twice as wide as high. It is excellent as a hedge plant or massed in groups. 'Green Mound' can be propagated from softwood cuttings in sand under mist when treated with 1000 ppm IBA.

Stephanandra incisa 'Crispa' is a graceful shrub selected for its dense low-mounding habit. The plant is wider than high, reaching a height of 2 to 3 ft, with finely textured foliage on thin, arching branches. It is hardy to Zone 4, easily transplanted, and has a fast growth rate. Although 'Crispa'

will do well in full sun, the plant does better with some protection from the hot summer sun. Both fruits and flowers are not significant. It is excellent when used as a ground cover, facer plant, or bank cover. Softwood cuttings root well when treated with 1000 ppm IBA.

MODERATOR KOLLER: Tom McCloud has a group of plants to present.

TOM McCLOUD: *Forsythia viridissima* 'Bronxensis' or bronx forsythia reaches a height of 2 ft and is flower and bud hardy to Zone 5 (Arnold Arboretum). Growth habit is low, dense, compact, true dwarf, and twiggy, bearing bright-green finely-toothed foliage and a profusion of bright yellow flowers in early spring. Excellent for banks, massing in beds, or foreground planting. Golden stems provide good winter interest. Rich medium moist, loam, with pH 6.5 to 8.0, and sun or light shade, are suitable conditions.

Itea japonica 'Beppu' or Beppu Japanese sweetspire is a vigorous, stoloniferous USDA introduction from the Beppu region of Japan. It produces a broad, spreading mass of dense branches and produces a smaller, more compact shape than *I. virginica*, but similar to *Leucothoe*. Dark green summer foliage turns red in fall; fragrant white flowers are borne in summer. It grows 2½ to 3 in in 6 years and is hardy to −6°F. 'Beppu' will grow in dry, acidic, poorly-drained soil, and in sun or shade.

Lonicera pileata, or royal carpet honeysuckle, grows to a height of 12 in and is hardy to Zone 5. Dark, shiny, semi-evergreen leaves and purple berries on stiffly horizontal branches give this twiggy, slow-spreading form considerable ornamental value in large beds, mass plantings, or as a ground cover, specimen or trimmed to a dwarf hedge. A real aristocrat in the ground cover group. A soil pH 6.0 to 7.5 is best.

Viburnum plicatum forma *tomentosum* 'Newport'® (P.P. 1891), or dwarf doublefile viburnum, grows to 2 ft high and 4 to 6 ft wide and is hardy to Zone 4 (Arnold Arboretum). The original plant was a chance seedling of *V. plicatum* forma *tomentosum*. It acts like its parent, except that the plant is quite dwarf. White blooms are smaller but double, like the Japanese snowball, and the leaves are less than half the size of *V. plicatum* forma *tomentosum*. Light loam to silty clay, moist, well-drained with pH 6.0 to 7.5, sun or partial shade are good growing conditions.

Malus 'Sugartime' P.A.F. Introduced by Lake County Nursery Exchange, Perry, Ohio, and found by Professor Emeritus Milton Baron, Campus Landscape Architect at Michigan State University. Upright oval habit reaching 18 ft, bearing white buds opening to pink flowers. Intense red fruit ½ in in diameter appears in October and persists until January, which hold until spring when new flowers appear. Full disease resistance of this plant has been documented over the past several years by Dr. Les Nichols of Penn State University.

MODERATOR KOLLER: Jim Cross has two plants to present.

JIM CROSS: *Arctostaphylos uva-ursi* 'Big Bear' appears to do well in the open cold winters of the East Coast, based on 5 to 6 years experience. It was found on a plant search high up in Montana near Big Bear Creek. The leaves are glossy, large, and not pointed. Being vigorous, 'Big Bear' develops a fast cover and is very ornamental. 'Big Bear' hardwood cuttings root readily with a minimum of help and care in a well drained medium. It is important to take short cuttings from the plant's center and stay away from terminal shoots.

Genista sagittalis, is a "broom" like *Cytisus* and is a member of the legume family. It is native to Europe and western Asia. This plant is deciduous but appears evergreen from the color of branches which are unusual in that the central woody core has broad wings on either side which are interrupted in an unusual manner at each joint. It is more like some of the cacti. The flowers are yellow and distinctly pea-like. Flowers also are produced on new wood so rabbit or winter damage will not affect its performance. *Genista sagittalis* grows in a prone position with branches developing in every direction from a central crown. It never takes on a brushed or wind-swept appearance. When it does come into flower it takes on a showy appearance. *Genista sagittalis* is easily rooted from hardwood cuttings in mid-winter with modest hormone treatment and with bottom heat.

MODERATOR KOLLER: Dale Herman has a hardy forsythia to tell us about.

DALE HERMAN: The Departments of Horticulture and Forestry, North Dakota State University (NDSU), Fargo, and South Dakota State University (SDSU), Brookings, in collaboration with the Arnold Arboretum, announce the introduction of *Forsythia* 'Meadowlark' (meadowlark forsythia).

In much of Canada and our more northern states, particularly the Northern Great Plains region, most commercially available *Forsythia* species and cultivars flower reliably only on branches protected beneath the snowline. The introduction of meadowlark forsythia will provide a shrub with vastly superior flower bud hardiness and showy spring flowers for planting in northern areas where forsythias were previously non-adapted.

The hybrid plant originated in 1935 via the breeding work of Sax and Dermen at the Arnold Arboretum. Meadowlark forsythia resulted from a cross of *Forsythia ovata* × *F. europaea*. Flint, while working at the Arnold Arboretum, observed a plant from this population in full bloom after the unusually cold 1966-67 winter, whereas a mass planting of *F.* × *intermedia* 'Spectabilis' which surrounded the new hybrid was nearly devoid of flowers. In the early 1970's the plant was distributed in cooperation with the USDA-ARS via the North Central Regional Plant Introduction Station, Ames, Iowa. For the past ten years 'Meadowlark' has blossomed consistently in North and South Dakota. The North Central Regional Plant Introduction subcommittee recognized its merits and approved the cultivar name 'Meadowlark'.

Meadowlark forsythia grows in a dense, regular spreading form to a height of 7 to 9 feet. It is a vigorous, fairly rapid growing shrub. Mature foliage is lush and dark ivy green, maintaining this color until late in the fall. A purple-bronze cast is the first indication of autumn color; however, under continued favorable fall conditions, the leaves usually change to golden-yellow. The foliage is of excellent quality and in Northern Plains trials has been virtually pest-free throughout the growing season. Bright yellow flowers are borne profusely in early spring. They are also deeper yellow in color than those of *F. ovata*. Plants begin to bloom when only 3 years old. Meadowlark is hardier than either parent and flower buds have not shown injury at temperatures of −35°F. Therefore, it is recommended throughout Zone 3 of either the USDA or Arnold Arboretum plant hardiness maps and it merits trial further north in Zone 2b. Plants also exhibit considerable drought tolerance.

Meadowlark forsythia is easily propagated from softwood cuttings in a 1:1 (v:v), peat-perlite medium with 90 to 96% rooting common. It can also

be propagated successfully using semi-hardwood cuttings, or hardwood cuttings (with bottom heat), and in limited numbers by layering.

Meadowlark forsythia will be officially registered in early 1984 and the first public commercial nursery distribution of this clone will be in the spring of 1985.

MODERATOR KOLLER: I will next present a plant for Sylvester March.

GARY KOLLER: *Deutzia crenata* var. *nakaiana* is native to Japan (Honshu, Shikoku, and Kyushu). The noteworthy characteristic of this plant is its low, compact growth habit of less than 18 in with gently arching branches, making it an excellent groundcover. The plant is covered with small white flowers in May. The leaves turn a deep burgundy in fall. The Arboretum's plant was acquired during a plant exploration to Japan in 1976, at the Watanabe Nursery, Gotemba City. Propagations have been distributed to arboreta and the nursery trade in the U.S.

The Nakai deutzia is easily rooted from softwood cuttings. The plant may also be layered. The lower branches root naturally as they touch the ground. Cuttings should be taken during the summer months. Treating the cuttings with a rooting hormone, such as IBA, will enhance rooting. *Deutzia crenata* var. *nakaiana* is of easy culture, doing best in a loamy soil with abundant moisture and full sun. Little or no pruning is required. It is free of any serious insect or disease problem. An occasional infestation of aphids may occur on the tips of soft new growth.

MODERATOR KOLLER: Kathy Freeland has six plants to show us from the Prairie Collection of the Chicago Botanic Garden.

KATHY FREELAND: *Anemone patens*, pasque flower, is an attractive herbaceous perennial with fern-like foliage. The principal attraction is the 2½ in solitary blue-to-purple flowers which appear in April and are followed by interesting feathery seed plumes.

Asclepias tuberosa, butteryfly weed, is an excellent choice for the dry, sunny garden, or rockgarden. Flowers are borne during summer on 12 to 24 in stems and may vary from yellow through all the orange shades to red.

Gentianopsis crinita (Gentiana crinita), fringed gentian, is a biennial noted for its deep blue flowers; produced on 2 ft plants. The fringed gentian grows best in a neutral grassy meadow.

Lithospermum canescens, hoary puccoon, is a perennial with white, downy foliage. Golden-yellow, tubular flowers appear from mid-May to mid-June and are highly ornamental. The plant may have a mycorrhizal requirement.

Monarda punctata, horse mint, is a member of the mint family with erect square stems than can reach 3 ft in height. Terminal rosettes of pale yellow flowers with purple spots are borne from July through October. Showy white or lilac bracts add color.

Zizia aurea, golden alexanders, has terminal flat clusters of yellow flowers which are borne in May and June. The leaves are doubly compound.

MODERATOR ALEXANDER: Harold Bruce from Winterthur Gardens will present a little known witchhazel.

HAROLD BRUCE: *Hamamelis mollis* 'Pallida' is characterized by large, fragrant, sulfur-yellow flowers produced in great abundance. When in

bloom its ornamental qualities and fragrance exceeds all other witchhazels in the Winterthur collection.

MODERATOR ALEXANDER: Robert Nicholson from the Arnold Arboretum will share information about the genus *Enkianthus*.

ROBERT NICHOLSON: *Enkianthus perulatus* is a member of the family Ericaceae and native to Japan. I feel that this is probably one of the most underused hardy shrubs. Its best feature is its fall color, a brilliant scarlet, although it also has an excellent floral display in early May. Unlike the other *Enkianthus* species, their flowers appear before the leaves. They are white, bell-shaped, and appear in clusters of 3 to 10 blossoms. It is a very hardy, long-lived shrub as we have specimens at the Arnold Arboretum that are approaching 100 yrs. in age. These are about 5 ft high although I have seen specimens that measured 9 ft high by 12 ft wide. In the United States it is mainly used as a specimen plant; the Japanese use it in hedgerows.

Another *Enkianthus* I would like to present is equally unusual. *Enkianthus campanulatus* var. *sikokianus* is also native to Japan and, like *E. perulatus*, has a fine fall color and floral display. Its flowers, when young and unopened, are a maroon with undertones of violet and when open are a dark brick-red with streaks of shrimp-pink. Our plant was out of University of Washington seed and a cutting from our plant, grown at Martha's Vineyard, Massachusetts, grew to 5 ft in just 6 yrs. This would be an excellent plant for walkways and patios but can be a bit tender in Zone 6.

A final *Enkianthus* is a cultivar I am naming *Enkianthus campanulatus* 'Renoir'. The type plant grew from seed received from the University of Edinburgh in 1923 and has been growing at the Arnold Arboretum since then.

It is distinctly different from the regular species with flowers that are pale yellow with pink lobes. The flowers which come in late May, are arranged in racemes about 1½ to 2 in. in length and number up to 11 blossoms. After 60 yrs the plant is 11 ft high by 10 ft wide.

Propagation of these three plants can be achieved by using a 5000 ppm IBA dip on softwood cuttings taken in mid-June and placed under mist. The cuttings should not be disturbed until they have over-wintered and broken bud.

MODERATOR KOLLER: I will conclude the New Plants session with one plant.

GARY KOLLER: In the Boston, Massachusetts area the American yellowwood *(Cladrastis lutea)* has proven itself as a landscape plant by being both dependable and robust. At the Arnold Arboretum we cultivate another ornamental *Cladrastis* species which, in North America, is probably unknown outside of botanical gardens. The plant is *C. platycarpa*, the Japanese yellowwood, which deserves attention by nurserymen due to its successful growth and flowering period.

The oldest plant at the Arnold Arboretum is about 64 years of age. This tree stands approximately 35 ft tall and spreads 40 ft. The branch structure is different than in *C. lutea* for there are more secondary and tertiary branches giving the tree a more dense and twiggy aspect. New season's growth ranges from 2 to 6 in in height.

This species produces terminal clusters of white to creamy white flowers in late June or early July, or several weeks after the American yellow-

wood. Flowering occurs in alternate years. Seedlings appear to take 12 to 14 years to begin the flowering cycle. Fruit resembles that on *C. lutea* but differs by having a marginal wing.

The foliage canopy of the tree is light enough to allow grass to grow up to the base of the tree. While root flare is visible directly at the base, rooting does seem to be deep. Arboretum trees are growing on a slight slope in a dry, gravely loam of acid pH. We grow a number of specimens and the lowest winter temperatures our trees have endured is approximately −10°F, with no apparent tissue damage or dieback.

The seeds available today were collected from Arnold Arboretum, accession number 10928. Germination is inhibited by a hard seed coat. In order to obtain maximum sprouting scarify the seeds for one hour in a bath of concentrated sulfuric acid, or soak the seeds for 12 hours in hot water, just off boil and allowed to cool gradually while steeping the seeds.

Thursday Evening, December 8, 1983

The thirty-third annual banquet was held in the Constellation Ballrooms of the Hyatt-Regency Hotel, Inner-Harbor, Baltimore, Maryland.

On behalf of the Society, an award was presented to Mr. Craig R. Adkins, Department of Plant Pathology, North Carolina State University, Raleigh, North Carolina, for the best graduate student award paper and to Dr. Frank Blazich, who was the advisor for the work presented in the paper by Mr. Adkins.

John McGuire made the following presentation:

AWARD OF MERIT

I will concentrate on the personal history of the 1983 recipient in an attempt to show you how his determination and courage led to his success as a plantsman of the highest regard. I could simply catalog his accomplishments which were many since his professional career spans 60 years but as I looked into this personal history, I was fascinated with it.

He first entered the world of horticulture at the age of 13 as an apprentice in a market garden. He continued to work as an apprentice at estates and gardens for 5 years when he went to a large nursery. He was now near a large city (Copenhagen) where he had the opportunity to go to school at night while working during the day. This was the first time he was exposed to plant breeding which would eventually become his profession. It was also here where he met a young lady who would eventually be his wife.

He began to think about coming to America and in 1922 he got the opportunity. His lady friend was not as enthusiastic about moving as he was but he promised her if he did not like it, he would return in 2 years. Otherwise, he would send for her. He migrated to Jewitt City, Connecticut where he worked

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as a carnation grower and, after 2 years, he attempted to bring his friend to American but she could not get into the country. He had to return and marry her there to get her into the country.

After a short time he went to work in landscaping and then the 1932 depression came and jobs disappeared. He decided to get a college education so he could find a job. He went to the University of Connecticut and sought admission but he was told that with no high school diploma and the fact he was 26 years old and married, he was a bad risk. They discouraged him from attempting a full-time enrollment.

They suggested he take a few courses as a special student with the understanding he must attain a grade of "C" or he would be dismissed. He enrolled for the full freshman program, including ROTC, for both the freshman and sophomore years, and while he was doing this he worked 30 hours per week in the nursery industry. His wife also worked and lived in Jewitt City.

He was then admitted with full status and he graduated in 4 years in botany with highest distinction. During this time, while studying and working to support himself, he was also conducting his own breeding projects with carnations in the university greenhouses.

When he graduated he met Dr. Sam Emsweller, who came east to take a position with the USDA. Dr. Emsweller was impressed with his breeding work and encouraged him to go to graduate school at the University of California at Davis. However, it was unclear if he would get an assistantship. After spending 4 years working night and day for his B.S. degree he was not sure he should go but his wife supported him and he wanted to do it.

The funds came through and he transferred to the University of California at Berkeley to work in genetics. Once again, because of his age, he was encouraged to work directly for the Ph.D. instead of starting first with the M.S. degree. He got the degree and a position as an instructor in floriculture. In 1945 he was offered a position at the Missouri Botanical Garden along with an Associate Professorship at George Washington University in St. Louis. In 1952 he was offered a professorship at the University of Connecticut, and he was back home.

During all of these years he continued to carry on his research in plant breeding. When he went from Connecticut to California he carried with him a pocketful of seeds; when he went to Missouri his research material took up so much room there was barely room in the car for his wife, and when he

returned to Connecticut he needed a 2½ ton truck to transport his research materials.

By this time you know of whom I speak. He has received honors for his work with orchids, carnations, and rhododendrons — the list of awards spans over 30 years.

His standards have always been of the highest and his work is highly regarded by all kowledgeable plantsmen, both at the commercial and the academic level.

Though he retired from the University of Connecticut in 1976, he is still active as a Professor Emeritus. He is still doing breeding work with rhododendrons in Connecticut and Rhode Island. Our recipient for the Award of Merit for 1983 is Dr. Gustav Mehlquist.

Friday Morning, December 9, 1983

The Friday morning session convened at 8:00 a.m. with Chris Graham serving as moderator.

TEN YEARS OF PLANT PROPAGATION PROGRESS

J.S. COARTNEY
Department of Horticulture
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

From time to time it is good to reflect on past accomplishments to assess one's rate of progress. This presentation will deal with some of the changes in plant propagation that have occurred during the past 10 years. The first item of progress that I want to bring to your attention is the printing in 1983 of a 4th edition of the Hartmann and Kester plant propagation text. This new edition deals extensively with findings that have occurred since the 1975, 3rd edition.

Significant changes in plastics and their diverse uses have occurred in the past 10 years. The new greenhouse coverings, which include UV inhibitors, have greatly extended the life of greenhouse coverings. Milky opaque plastics have greatly simplified winter protection of container-grown stock and now show promise in providing an ideal environment for winter propagation. Plastics are now available that include reflective surfaces to control light intensity; others include mesh structure for increased strength; some are perforated with tiny pores to allow for water penetration; and some are black on one side to exclude light and white on the other side to reflect

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light. All of these variations allow us to choose plastic designed for almost any environmental condition desired. Further use of plastics that have come into use in the past 10 years include bags for growing plants, use of plastic pipe to build simple inexpensive houses, and new wrapping materials for grafting.

The oil crisis brought many changes to the propagator. The hardships caused by this crisis brought out the creative nature in the propagator and has resulted in many changes in operations. Summer propagation, sunken greenhouses, movable thermal curtains, thermo blankets, and alternate heat sources became common topics of discussion among propagators. Many operations have made major design changes to become more energy efficient. A large Virginia greenhouse operation is currently relocating to take advantage of low-cost, hot-water heat provided by an electric power plant. Another greenhouse operation is studying the feasibility of linking with a poultry operation in order to utilize body heat from chickens to aid in heating the greenhouses. Several operations have converted from raised .propagation beds to ground beds to improve energy efficiency.

During the past 10 years space-age technology has affected everyone and the propagator is no exception. Solid state, low-voltage electronic timers have replaced the older style timer that worked off 115 volts and had contact points that easily corroded and malfunctioned. Of course, there is also the computer which is now common place in even small businesses. In addition to the traditional bookkeeping functions, computers can be programmed to provide total control of the complex greenhouse operations (i.e. automated misting, heating, ventilation, and lighting). A newly constructed, commercial operation in Virginia will use computer control to provide a day/night temperature cycle that gradually raises and lowers the temperature to approximate natural diurnal fluctuations. Linking the computer system to the telephone has provided various types of alarms to alert for mechanical failures during unattended hours. An important function for computers that should not be overlooked is their value in planning or decision-making. Programs are now being perfected that will cover almost any type of analysis desired.

Improved electronic environmental control has prompted dramatic increases in softwood propagation of cultivars that previously had to be grafted or budded. Propagators have not only learned to handle the soft tissue during the preparation and rooting cycle, but also have learned how to handle the cutting in order to survive the first winter. Debate continues

as to the hardiness of a cultivar propagated on its own roots as opposed to being placed on a rootstock. Production of cultivars on their own roots has certainly benefited the production of those plants that commonly sucker from below or above the graft union. It would be good if all nursery catalogs provided information as to whether a plant was propagated on its own roots or by grafting.

High humidity propagation has been reinvented in the last 10 years. When I grew up, high humidity propagation was a quart fruit jar placed over an unrooted cutting on the north side of a building. Plastics and shading have now allowed this simple technique to be performed on a large scale. As expected, some plants give better results using high humidity than if misted. One must be cautious about making such comparisons as results are compared to a single misting cycle which may or may not be the optimal mist cycle for the plant in question.

Fortunately, progress has also been made in the area of fungicides for the propagator. Softwood cutting and high humidity propagation techniques provide an environment especially suited to pathogen development and a good fungicide program may mean the difference between success and failure.

New developments have also occurred in the area of budding and grafting. The chip bud has provided success with many cultivars that did not respond well to other methods of budding or grafting. New methods of securing the bud to the stock and protecting it from drying have also been developed. New types of budding rubbers and an assortment of plastic ties are now available for a variety of uses. In addition to the conventional wax or water base asphalt coatings, a new latex base material called "Gold Seal" is now available. Another material new to the propagator is Parafilm, a wax-impregnated plastic that has been widely used in laboratories for many years. Recently, Parafilm has been found to be quite suitable for covering chip buds of roses. The material stretches and sticks without tying and a bud will grow through it. No doubt the technique developed with roses will be applicable to other plants as well.

Hot callusing is a simple new technique that allows for localized heating of a graft union without heating the remainder of the scion or stock. This allows for rapid healing of the graft union without promoting premature bud break of the scion. The same general principle exists when an unrooted cutting is bottom heated to promote root growth without causing bud break.

Techniques for accelerated growth of many plants have been perfected in the past few years. By controlling temperatures and light it has been possible to greatly reduce the time required to produce plant liners. With some plants this has been primarily through control of day length, but with various conifers, cold cycles have been used to produce more than one growth cycle per year.

Micropropagation has, no doubt, become the superstar of the last 10 years. During this period, it has moved from the realm of laboratory fantasy to commercial production. No longer is it confined to relatively easy-to-culture herbaceous plants but includes some of the very difficult-to-propagate woody plants such as *Kalmia latifolia*. Tissue culture has also served a very useful purpose in virus elimination from various fruit clones. The future of tissue culture is even more exciting in that it will open many new possibilities in the area of plant breeding. It has the potential for rapid development of pure (homozygous) breeding lines that would otherwise take many generations of inbreeding to develop. It also has the potential for changing chromosome numbers of cultured cells. Plants produced from the cells with new chromosome numbers would be capable of crossing with a new group of related plants bearing the same chromosome number.

Various advances have been made in the area of mechanization during the last 10 years. These involve all phases of the nursery business from materials handling, to potting and harvesting. Many plants are now produced in containers designed for mechanical planting. The Weyerhaeuser-owned facility, Oakdell at Apopca, Florida, represents the ultimate in mechanization with rolling bench tops and computer controlled assembly of various plants needed to fill a given order. Small operations have also made advances in the area of mechanization. It may be a better way to fertilize, to bend a pipe, or direct rooting to reduce handling, but certainly significant within that particular operation.

Many items developed within the past few years are still in the research stage but will prove to be practical in future years. There are new growth regulators and new media ranging from bark to composted sludge. Microwave generators, small and large, have been shown to be effective for media pasteurization. Hydroponics in a variety of forms continues to be researched and placed into production. A refinement of the hydroponic technique has led to "air rooting" where roots are suspended in air and moistened at frequent intervals with a nutrient mist. Research continues with CO_2 enrichment of the

greenhouse environment. The CO_2 can be supplied as a gas or through the mist system.

In summary, it appears that the last 10 years have indeed been productive in terms of advances in plant propagation. Current research indicates that the next 10 years will also supply us with many more changes.

WITCHES'-BROOM COLLECTION OF CONIFERS AND THEIR PROPAGATION

SIDNEY WAXMAN

Department of Plant Science
University of Connecticut
Storrs, Connecticut 06268

Witches'-brooms are dense shrub-like growths that occur as a result of the mutation of buds (Figure 1). They are found mainly on conifers and generally retain their dwarf and dense character when propagated vegetatively (1, 2). The grafting of witches'-broom tissue has been done since 1874 and is the origin of such dwarf evergreens as *Pinus sylvestris* 'Beauvronensis' and *Pinus nigra* 'Hornibrookiana'.

Figure 1. A witches'-broom found on an eastern white pine.

The number of different forms of such dwarf plants is limited by the number of witches'-brooms found. A much larger number of different plant forms can be obtained, however, from the seed of the broom.

Over 20,000 seedlings of *Pinus strobus, P. sylvestris, P. resinosa, P. banksiana, P. rigida, P. densiflora, Picea abies,*

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Larix laricina, and *Tsuga canadensis* have been grown at the University of Connecticut since 1964 and have produced many interesting forms that are dwarf, semi-dwarf, weeping, spreading, upright, and prostrate, as well as variegated (4). Table 1 illustrates the wide range of height and width among dwarf seedlings from different witches'-brooms.

Table 1. A comparison of the dimensions (height × width) of the largest and the smallest witches'-broom seedlings.

Species	Age	Smallest	Largest
	years	H × W	H × W
Picea abies			
Witches'-broom No. 1	9	1½ × 2 ft	2½ × 4 ft
Witches'-broom No. 2	4	6 × 5 in	20 × 16 in
Pinus strobus			
Witches'-broom No. 1	19	11 × 9 ft	13 × 11 ft
Witches'-broom No. 2	19	1½ × 2½ ft	2½ × 6 ft
Pinus resinosa			
Witches'-broom No. 1	11	2 × 4½ ft	3 × 6 ft
Witches'-broom No. 2	12	1½ × 2 ft	3 × 3 ft
Tsuga canadensis			
Witches'-broom No. 1	4	9 × 7 in	27 × 22 in
Witches'-broom No. 2	12	1 × 2 ft	7 × 6½ ft

These seedlings have also exhibited variations in needle color, needle length, stem thickness, branch rigidity, branch density, and branch orientation. This variation offers a wide choice of shapes and sizes of plants from which one may select. Although I have obtained seedlings from many different brooms, I constantly look for additional ones because the progenies from different brooms may differ significantly from one another. In other words, in addition to obtaining variation among a group of seedlings from a single broom whose progeny, on the whole, have a slow rate of development and are extremely dwarf, we also can obtain variation among a population from a second broom whose rates of development are considerably greater. In the latter population, the plants are much larger than those of the former although they retain the dense branching character. Figure 2 illustrates the growth differences among progenies from three different witches'-brooms.

In another example, but with Canadian hemlock, one population had seedlings whose branching habits varied from horizontal to weeping, whereas the progeny from another broom had branching habits that were ascending.

The purpose of this project is to introduce new, interesting forms of dwarf conifers to the nursery industry. As of this date the following plants have been named and scions distributed to cooperating propagators.

Figure 2. Three groups of seed-grown dwarf white pines, all the same age (12 years), which were obtained from three different witches'-brooms.

1. *Pinus strobus* 'Sea Urchin'. A miniature shrub having very short needles 1¼ in. long. After 19 years of growth it has developed into a low mound having a height of only 1½ ft and a width of 2½ ft. The foliage has a bluish-green appearance (5). It is propagated by grafting, since rooting of cuttings has not been successful.

2. *P. strobus* 'Green Shadow'. A multi-trunk dwarf shrub with dark green foliage. It has grown 5½ ft tall and 7 ½ ft wide in 16 years. Its form, shrub-like in its formative stages, becomes more tree-like with age. The needles, which are 3 in long and thicker than the other cultivars, are retained on the plant for 3 years while most white pines retain their needles for only 2 years. This cultivar is relatively easy to root having been rooted successfully in February, March, April, September and November.

3. *P. strobus* 'Blue Shag' (5) is a dwarf shrub but with a faster annual rate of growth than 'Sea Urchin' or 'Green Shadow.' Its bluish-green needles are 2½ in. long. The overall dimensions of the plant after 8 years of growth are 3 ft tall, and 5½ ft wide. Rooting of cuttings has been moderately successful (20%).

4. *P. strobus* 'UConn' (4) is a relatively rapid growing but fully branched tree. It has obtained a height of 10 ft and a diameter of 7 ft in 15 years.

5. *P. resinosa* 'Sand Castle' is a broadly ovate and very dense shrub (Figure 3). It has tufts and short dark green needles and has a growth rate of 3½ to 4 in. per year.

Its dimensions after 10 years are 4 ft tall and 4½ ft wide. It should be grafted. Rooting of cuttings has not been successful.

6. *P. resinosa* 'Thunderhead' is a low vigorous shrub more broad than tall. It has long dark green needles arranged in tufts and has grown 4 ft tall and 5 ft wide in 10 years. It is propagated by grafting. Rooting of cuttings has been difficult (2%).
7. *Tsuga canadensis* 'Florence' is a low and spreading with layered branches; its dimensions, after 12 years, are 1½ ft tall and 4½ ft wide. It is propagated by grafting and has had some success by cuttings (20%).

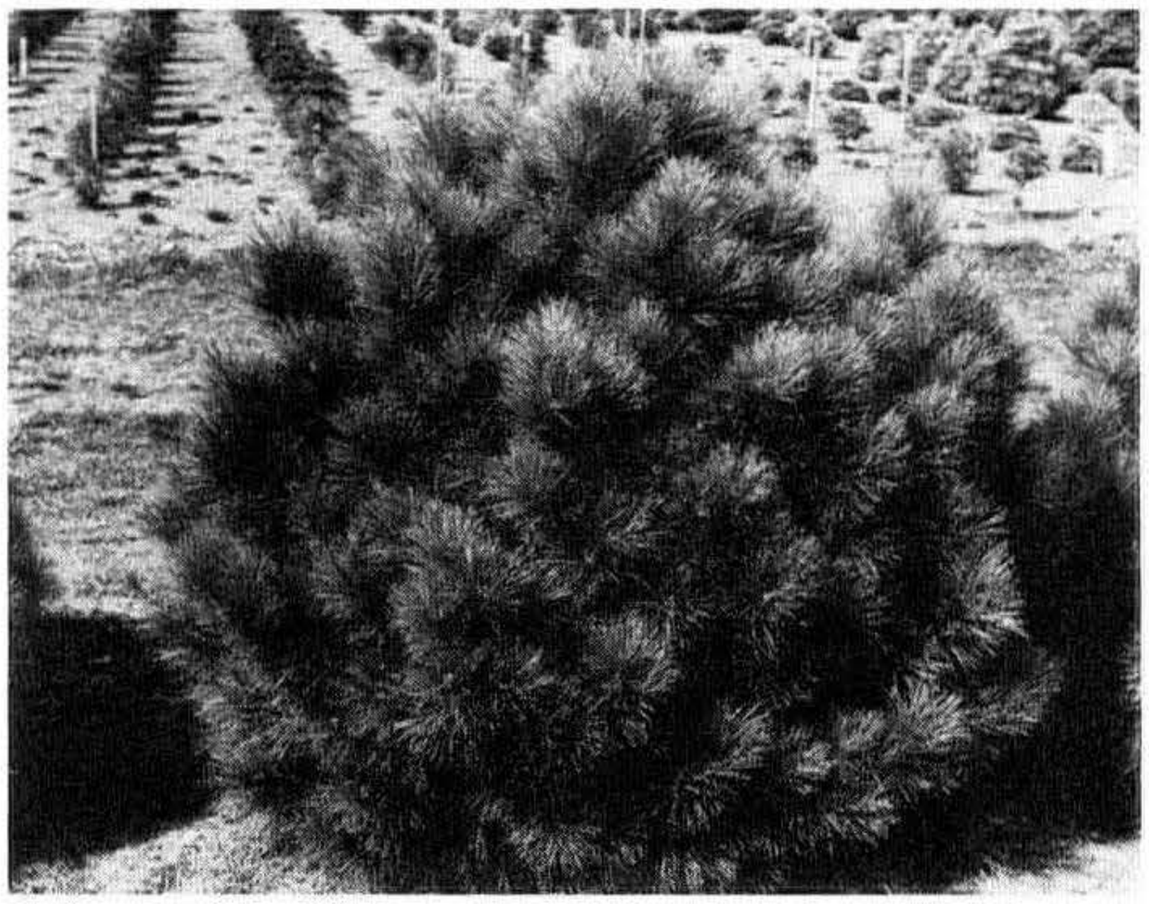

Figure 3. A red pine witches'-broom graft, *P. resinosa* 'Sand Castle'.

In general, among the white pines, rooting of cuttings has been most successful on cuttings taken from young seedlings. Cuttings taken from 4-year-old seedlings rooted 60% while those taken from 5-year-old plants rooted only 29% (3). Among the seedling obtained from various witches'-brooms, those exhibiting the highest rooting percentages were taken from the more rapidly growing forms, while cuttings taken from the very dwarf forms were very difficult to root.

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ROLE OF STRATIFICATION, TEMPERATURE, AND LIGHT IN FRASER FIR SEED GERMINATION

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Abstract. Fraser fir *(Abies fraseri)* seed germination was examined as affected by cold-moist stratification, temperature, and light. There were strong interactions among these factors in the germination response. Germination was accelerated by cold-moist stratification and/or warm germination temperatures. Stratification periods up to 12 weeks improved germination at low temperatures (8-hr/16-hr thermoperiod of 20°/10°C), whereas 8 weeks was sufficient for seed germinated at high temperatures (30°/20°C). Germination was influenced by temperature regime, but temperature and light sensitivity decreased with increased durations of stratification. Except at low temperatures, a close relationship existed between daily heat input and germination. Maximum germination occurred at 500 to 600 degree-hours per 24-hr cycle. A 1-hr daily light treatment during the 8-hr temperature cycle broadened the temperature range for optimum germination. For a 42-day germination period, the effect of a daily 1-hr light treatment was essentially equivalent to 4 weeks stratification at 4°C.

Fraser fir *(Abies fraseri)* is indigenous to restricted areas of the Southern Appalachians (13), and is used commercially for Christmas trees, ornamentals, and Yuletide greenery. Although propagation can be achieved by both sexual and asexual means, commercial regeneration is limited to seed propagation. Despite widespread commercial use of sexual propagation there is little information available concerning the influence of various pre-germination treatments, such as cold-moist stratification. One report dealing specifically with seed stratification of this species concluded the practice was of doubtful commercial value (16). Similarly, little is known about such environmental factors as light and temperature on the germination process. Therefore, the objective of the following studies was to examine the effects of cold-moist stratification, temperature, and light on Fraser fir seed germination.

MATERIALS AND METHODS

Two experiments were conducted. Experiment 1 examined the role of cold-moist stratification on Fraser fir seed germination; Experiment 2, the influence of temperature on

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seed germination. Earlier work with Fraser fir (5) indicated that a 1-hr daily light seed treatment would significantly improve 42-day germination, so this treatment was included in both experiments to determine how it would influence the relationships between stratification and temperature. No attempt was made to quantify the relationship between light (duration, quality, or illuminance) and germination.

Seed was collected in the fall, 1981, by the North Carolina Forest Service from Roan Mountain (36° 01′ N. lat.; 82° 05′ W. long.; elev. = 1900 m). Damaged, undersized, or resinous seeds, as well as those appearing abnormal, were removed by hand prior to initiation of the experiments. Cutting tests and tetrazolium tests indicated germinative capacity of the graded seed to be 74 and 77%, respectively (1).

Seeds were germinated in 9-cm, covered, glass Petri dishes containing moist blotters. Dishes scheduled to receive a daily light treatment were placed inside black sateen cloth bags immediately after sowing. Dishes were randomized on metal trays, and placed in Pfeiffer germinators maintained within ±1°C of the set point. Relative humidity was approximately 100% in each germinator. Germination counts were recorded every 3 days for 42 days and seeds were considered germinated when radicals were ≥2 mm in length. Seeds with reversed embryos and multiple or abnormal radicles were not included in germination counts. Seeds were sprayed every 3 days with an aqueous suspension of benomyl containing 300 mg per liter (1). Approximately 0.8 ml of liquid was applied on each occasion, and appeared not to result in excessive moisture in the dishes. For dark-treated seeds, germination counts and benomyl applications were carried out under a green safelight known not to affect germination.

An 8-hr/16-hr thermoperiod was utilized, and seeds receiving a light treatment were subjected to a 1-hr daily illumination (measured with a cosine corrected LICOR LI-185 quantum/radiometer/photometer) from cool-white fluorescent lamps during the 8-hr cycle. The photosynthetic photon flux density (400 to 700 nm) was 21 to 27 μmol $m^{-2}s^{-1}$ (1.6 to 2.0 klx). Because germinators were not equipped with lights, the light treatment was imposed by setting trays on benches adjacent to the germinators.

Experiment 1: Stratification, temperature, and light. Dry sand was seived through a 16-mesh screen, and the fine separate retained. One hundred graded seeds were mixed with 40 ml moist sand (10 dry sand:1 water, by vol.) and placed in a 500 ml nonvented, polyethylene freezer bag. A total of 80 bags were prepared and placed in a dark 4°C cold-room for 0, 4, 8,

12, or 16 weeks. At the designated intervals, 16 randomly selected bags were removed. Seeds were separated from sand by flushing with tap water in a colander and were then transferred to dishes. Eight dishes were placed on an 8-hr/16-hr temperature regime at 30°/20°C; 8 at 20°/10°C. Within each temperature regime, 4 dishes received a 1-hr daily light treatment; 4 did not.

Experiment 2: Temperature and light. Half the seeds were stratified for 33 days at 4°C, while the other half were kept in a sealed polyethylene bag (4 to 6% moisture content) at −17°C. Stratified seed was removed from the cold room, air dried overnight at room temperature (22°C) to facilitate handling, and graded and counted into dishes, each with 70 seeds. Twenty temperature regimes were established, each consisting of one of 4 different temperatures (15°, 20°, 25°, and 30°C) during the 8-hr cycle in factorial combination with one of 5 different temperatures (10°, 15°, 20°, 25°, and 30°C) during the 16-hr cycle. Temperatures during the 8- and 16-hr cycles should not be interpreted as day/night temperatures because half the seeds were germinated in darkness and the remainder received only 1 hr of light during the 8-hr cycle. Eight dishes of stratified seed and 8 dishes of nonstratified seed were randomly assigned to each of the 20 temperature regimes. For each stratification treatment, 4 dishes, received a 1-hr daily light treatment; 4 did not.

Response surfaces (14) were developed using linear and quadratic effects of 8- and 16-hr temperatures and their respective interactions. Two-dimensional diagrams of percent germination were plotted for various combinations of 8- and 16-hr temperatures using as data points the maximum germination values for each of the 20 temperature regimes. This technique was similar to one taken earlier to describe growth of Fraser fir seedlings at different day/night temperatures (12). Percent germination was examined as a function of daily degree-hours. Using an 8-hr/16-hr thermoperiod, daily degree-hours were computed for the 20 temperature regimes as follows: (8 × short cycle temperature) + (16 × long cycle temperature). This approach was similar to one used earlier (11) to describe seedling growth of several conifer species as affected by different day/night temperatures. Periodic germination rate was calculated as total germination during each 3-day interval, divided by 3. In concept, this rate was calculated like a periodic growth increment in forest stands (6).

RESULTS

Stratification. Stratification of the seeds enhanced total germination, particularly at low temperatures (20°/10°C) and in darkness (Figures 1 and 2). Under such conditions, total germination after 42 days was increased significantly (t-test, 5% level) by stratification periods up to 12 weeks. At higher temperatures (30°/20°C), 8 weeks stratification was sufficient, especially for seed which received a daily light treatment (Figure 1). In general, germination accelerated with increased duration of stratification. For seed stratified 16 weeks and germinated at 30°/20°C, half the potential germination was realized by the 9th day, and germination was virtually complete by the 20th day (Figs. 1, 2, and 3). Even after 42 days, germination of nonstratified seed at low temperatures (20°/10°C) was less than half completed. At that time, germination was proceeding steadily at approximately 1% per day (Fig. 3).

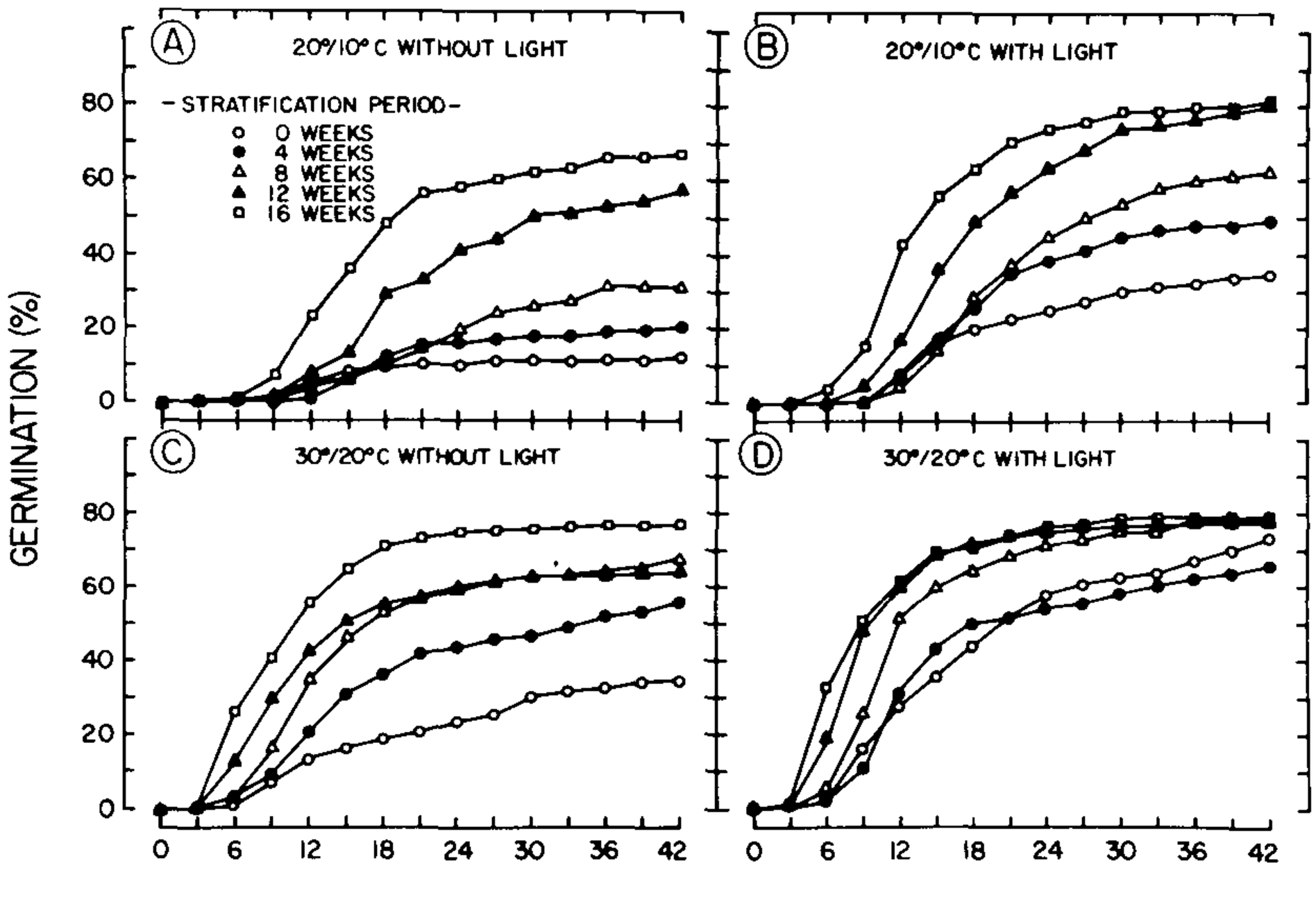

Figure 1. (Expt. 1) Influence of cold-moist stratification, temperature, and light on Fraser fir seed germination. (A) germinated in darkness at 20°/10°C; (B) germinated at 20°/10°C with a 1-hr light treatment during the 8-hr, 20°C cycle; (C) germinated in darkness at 30°/20°C; (D) germinated at 30°/20°C with a 1-hr light treatment during the 8-hr, 30°C cycle. Legend in (A) applies to all figures.

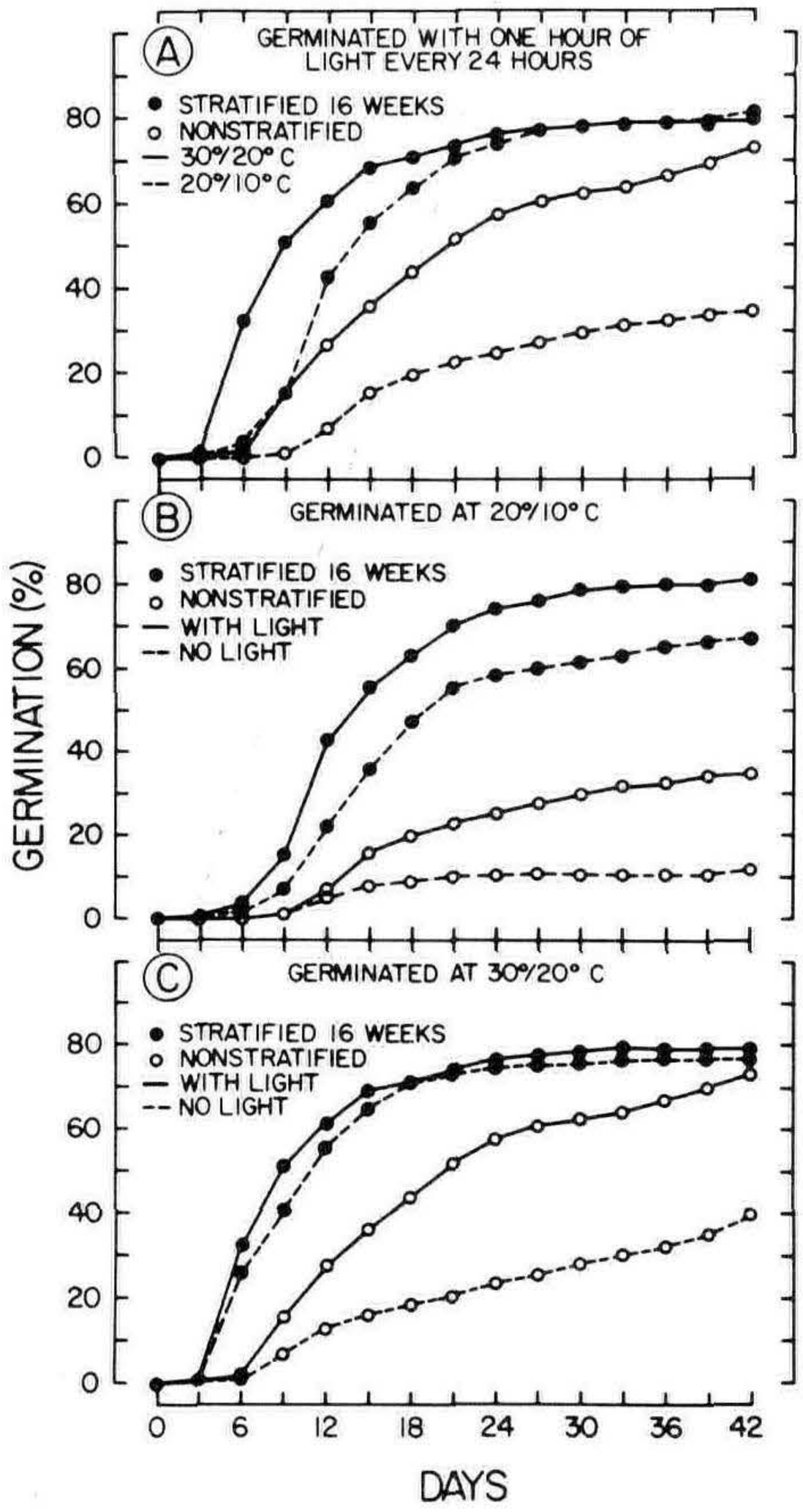

Figure 2. (Expt. 1) Total germination of Fraser fir seed after 42 days as affected by cold-moist stratification, temperature and light. (A) germination as affected by stratification and temperature for seed which received a 1-hr light treatment during the 8-hr temperature cycle; (B) germination at 20°/10°C, with and without a daily 1-hr light treatment during the 8-hr, 20°C cycle, as affected by stratification; (C) germination at 30°/20°C, with and without a daily 1-hr light treatment during the 8-hr, 30° cycle, as affected by stratification.

Temperature. Temperature had a marked effect on seed germination; its influence was affected by the duration of stratification and the presence or absence of light (Figure 4). In 3 of the 4 stratification and light treatments, maximum germination occurred at an 8-hr/16-hr temperature regime of 15°/25°C; 20°/25°C in the fourth. Total germination was closely related to the temperature of the 16-hr cycle, as evidenced by

the vertical orientation of isolines. Response surfaces (not shown) accounted for 83 to 88% of the variation in 42-day germination. For seeds which received a daily 1-hr light treatment, total germination decreased sharply and steadily as the temperature of the 16-hr cycle fell below 15°C, and reached a minimum of 10 to 20% at 10°C (Figure 4). A similar but more gradual decline occurred in darkness when the temperature of the 16-hr cycle fell below 22°C. Constant temperatures approaching 30°C noticeably decreased germination, especially with a light treatment, and killed seedlings soon after germination. With stratified seed, the range of temperatures (16-hr cycle) for optimum germination was broadened by a 1-hr daily light treatment. Total germination of nonstratified, nonirradiated seed was not only much lower than that for other treatments, but there was also a less clearly defined relationship between germination and the level of the 8- or 16-hr temperature cycles.

In addition to being closely related to the temperature of the 16-hr cycle, total germination was also a function of daily heat input (Figure 5). Over the range of 280 to 720 degree-hours, the relationship was quadratic with maximum germination at 500 to 600 degree-hours per 24-hr cycle. The range for optimum germination was widest for stratified seed which received a daily light treatment. Germination decreased linearly as daily heat input exceeded 560 degree-hours. With the exception of stratified seed which did not receive light, the relationship between heat input and germination was less clear at heat inputs $\leq$400 daily degree-hours.

Temperature influenced time course of germination as well as periodic germination rate (Figure 3). Periodic germination of stratified seed peaked between the 3rd and 6th day at 30°/20°C; the 9th and 12th day at 20°/10°C — an average difference of 6 days (Figure 3). The same pattern was evident for nonstratified seed, except that each peak occurred about 3 days later.

Light. Although interpretations are limited concerning the effects of light, several conclusions are warranted. Fraser fir exhibited no obligate light requirement for seed germination, but germination was enhanced by a 1-hr daily light treatment (Figure 1). The stimulatory effect of light was most evident for nonstratified seed and at low germination temperatures (Figures 1, 2, and 4), and decreased with increased durations of stratification (Figure 1). At low germination temperatures (20°/10°C), a daily 1-hr light treatment significantly improved 42-day germination (t-test, 5% level) for seed stratified up to 12 weeks, whereas at 30°/20°C it significantly increased 42-day

germination only for nonstratified seed (Figure 1). A daily 1-hr light treatment did not affect the temperature for maximum germination but broadened the temperature range for optimum germination (Figure 4). This was most pronounced for seed stratified less than 8 weeks, particularly nonstratified seed (Figure 1). A daily 1-hr light treatment increased the maximum periodic germination, but did not alter time course of germination (Figure 3).

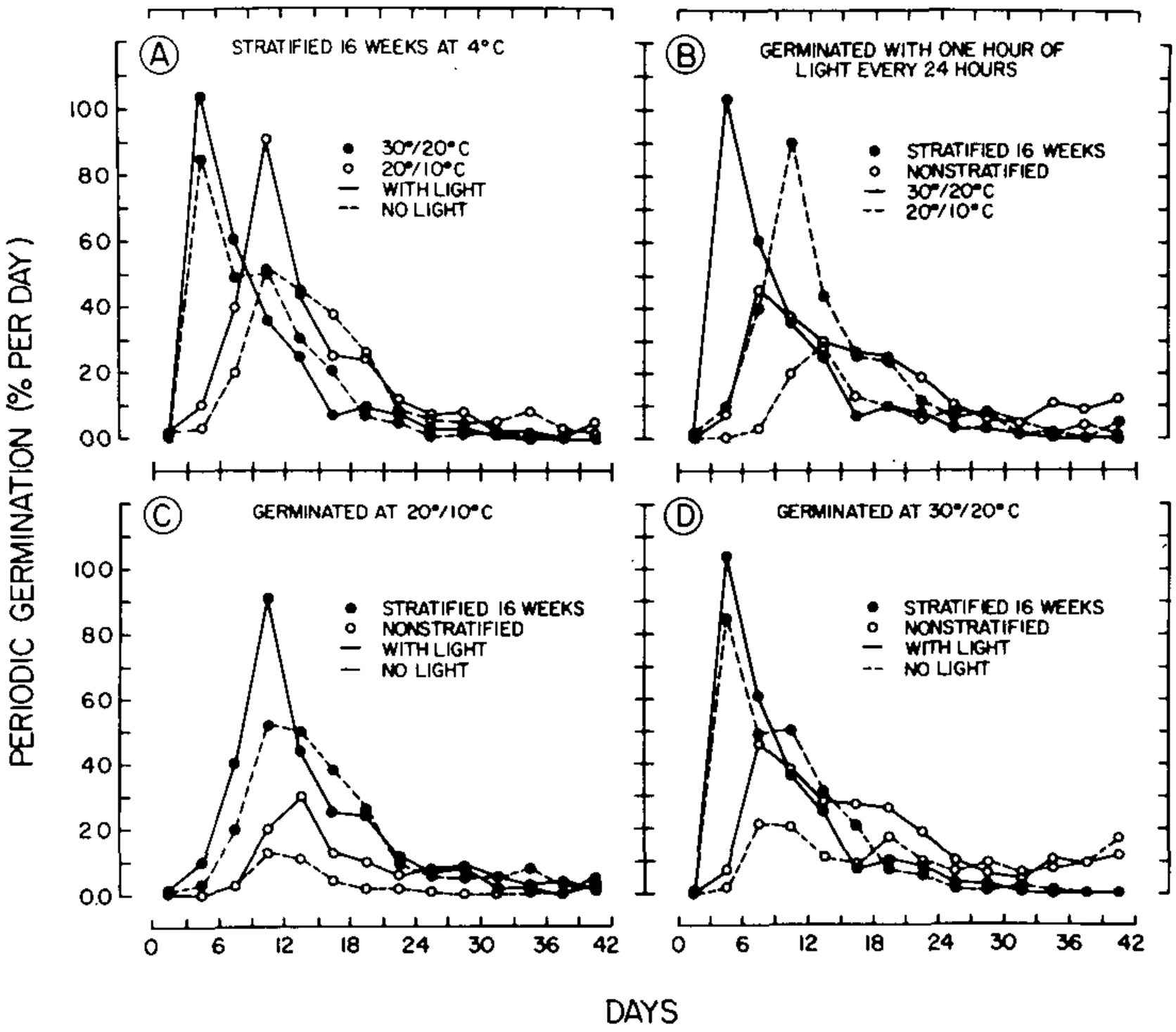

Figure 3. (Expt. 1) Periodic germination of Fraser fir seed as affected by cold-moist stratification, temperature and light. (A) germination under different temperature regimes, with and without a 1-hr light treatment during the 8-hr cycle, following 16 weeks stratification at 4°C; (B) germination as affected by stratification period and germination temperature for seed which received a daily 1-hr light treatment during the 8-hr cycle; (C) germination at 30°/20°C, with and without a daily 1-hr light treatment during the 8-hr, 30°C cycle, as affected by stratification period; and (D) germination at 20°/10°C, with and without a daily 1-hr light treatment during the 8-hr, 20°C cycle, as affected by stratification period. Each data point is plotted at the midpoint of the time interval for which it was calculated.

DISCUSSION

There were strong interactions among the 3 factors, as has been noted similarly for other conifer species (2, 3, 8, 17, 19). A case in point is the loss of sensitivity to temperature and

light with increased durations of stratification (Figures 1, 2, and 4). Even though stratification makes temperature a less critical factor and allows more rapid germination at low temperatures, the relationship is influenced by light. At short durations of stratification (0 to 4 weeks), light is apparently more important than stratification in broadening the range of temperatures for optimum germination of Fraser fir, and increasing total germination at low temperatures (Figure 4). In its effect on total germination, a 1-hr daily light treatment was approximately equivalent to 4 weeks of stratification at 4°C. For stratified seed, sensitivity to temperature was most pronounced in darkness (Figure 4). After only 4 weeks stratification, a 1-hr daily light treatment reduced temperature sensitivity to the extent that germination was relatively high for any constant temperature between 18° and 27°C. The same light treatment was of less consequence, however, following long periods of stratification (Figures 1 and 2).

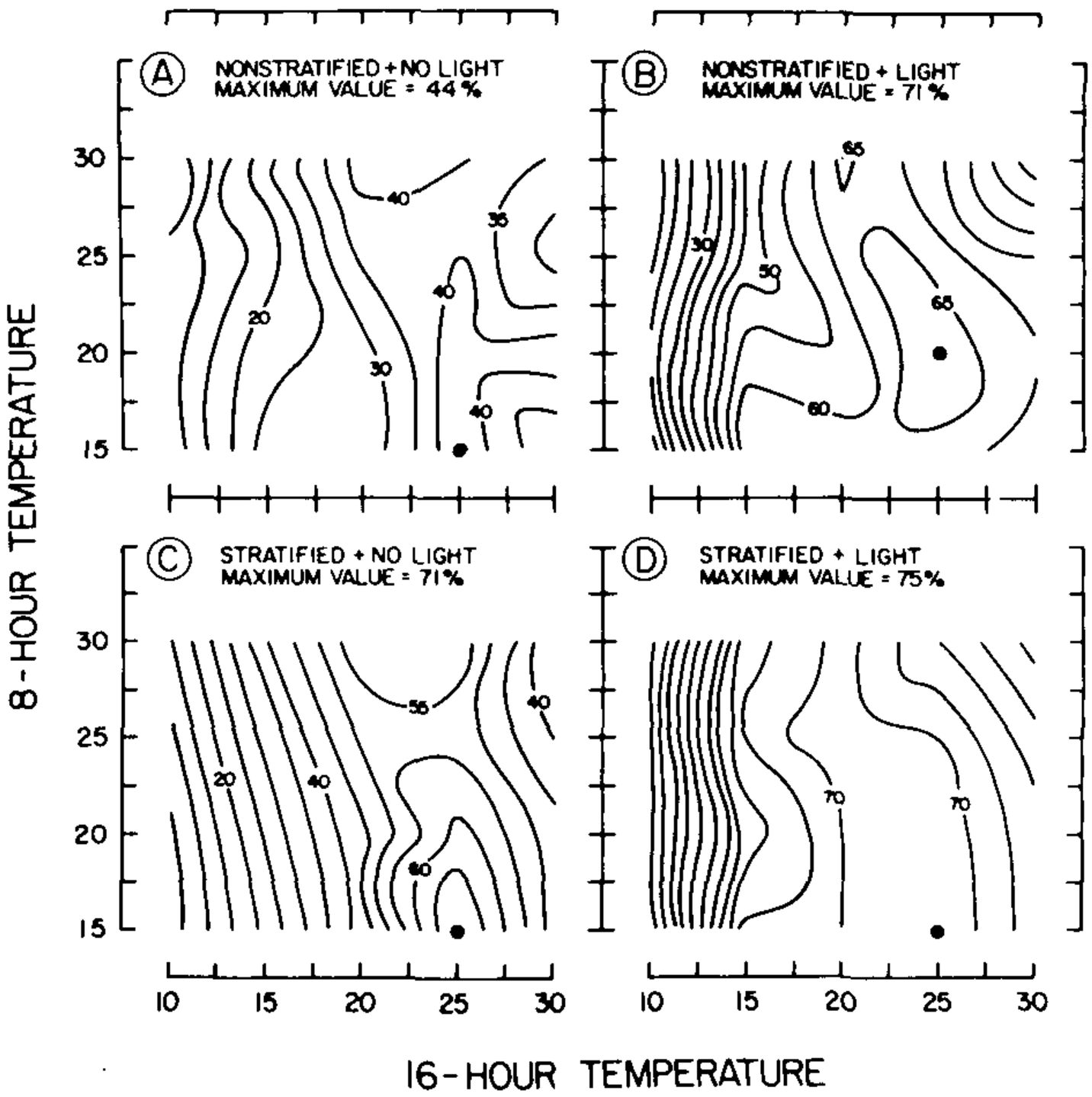

Figure 4. (Expt. 2) Germination of Fraser fir seed at different temperature regimes. The thermoperiod was 8 hr/16 hr. (A) nonstratified seed germinated in darkness, (B) nonstratified seed subjected to a daily 1-hr light treatment during the 8-hr cycle, (C) stratified seed germinated in darkness, (D) stratified seed subjected to a daily 1-hr light treatment during the 8-hr cycle. Stratification was for 33 days at 4°C. Maximum germination value signified by ●.

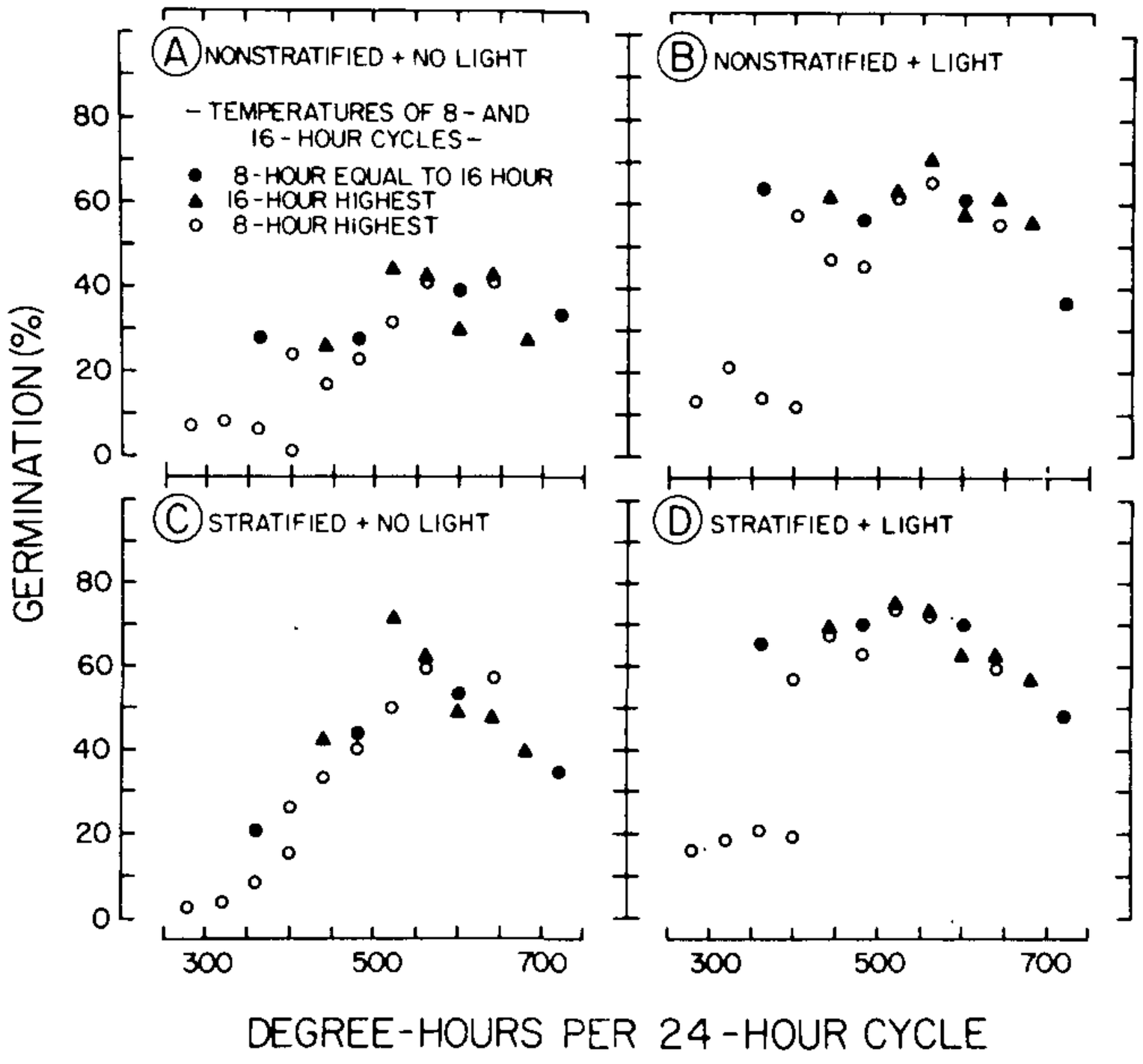

Figure 5. (Expt. 2) Germination of Fraser fir seed as affected by heat input during an 8-hr/16-hr thermoperiod. (A) nonstratified seed germinated in darkness, (B) nonstratified seed which received a 1-hr light treatment during the 8-hr cycle, (C) stratified seed germinated in darkness, (D) stratified seed which received a 1-hr light treatment during the 8-hr cycle. Stratification was for 33 days at 4°C. Legend in (A) applies to all figures.

The time required for germination to follow its course was quite variable, depending on the stratification period, germination temperature, and light treatment. This has implications in selecting the duration of laboratory germination tests. If tests are conducted at warm temperatures (30°/20°C) and include a daily 1-hr light treatment, they need not exceed 28 to 30 days for seed stratified 8 or more weeks; 42 days for seed stratified 4 weeks (Figure 1). Based on these experiments, it is not known how these limits would be affected by light treatments of longer duration. On the other hand, at lower temperatures (20°/10°C) and/or in darkness, more time is required, perhaps 60 to 90 days, to realize most of the potential germination for seed stratified 8 weeks or less. In outdoor nurseries — even those well below the elevation of natural stands, nonstratified Fraser fir seeds commonly germinate throughout the first growing season following planting; a few not until the second season. While this is a useful adaptation to survive weather fluctuations in the native habitat, it is troublesome to nursery-

men who prefer faster germination. Stratification causes rapid and complete germination in a relatively short time over a wide range of environmental conditions. Quick establishment and more uniform stands would facilitate scheduling of cultural treatments.

Minimum and maximum temperatures for germination were not determined. Forty-two-day germination was less than 20% at 15°/10°C (Figure 4). Earlier work indicated that germination of nonstratified seed was practically nil after 42 days at a constant 10°C and zero at 35°C, even with a daily 1-hr light treatment (5). Although these results agree well with those for other *Abies* and *Picea* species (4, 10, 15), seeds of many conifer species can germinate at temperatures between 0° and 5°C given sufficient time (2, 8, 9, 17, 18). At the other extreme, germination occurred at constant 30°C, but was below optimum (Figures 3 and 5), and germinants did not survive the 42-day test.

It is not possible to identify the optimum 8-hr temperature for germination, based on Experiment 2, because maximum germination occurred at the periphery of the data in 3 of the 4 stratification-light treatments (Figure 4). Perhaps germination would have been greater for 8-hr temperatures less than 10°C. The likelihood for this seems small for stratified seed because germination was virtually complete (based on tetrazolium test) after 42 days at 15°/25°C and obviously could not have been much greater than the observed maximum. The uncertainty is greater however, for nonstratified, nonirradiated seed, considering the low 42-day germination and the weak relationship between germination and temperatures of the 8-hr or 16-hr cycles.

Seed tended to mold during cold stratification periods >8 weeks. The type of fungus(i) was not identified, but observations suggested a form of *Rhizoctonia*. One would thus have to weigh the advantages of long stratification periods against the risk of losing seed as a consequence of mold. Fungicide treatments prior to stratification deserve study, and different stratification procedures might also diminish the problem. Other potential problems of long-term cold stratification might be the tendency for seed to germinate during treatment (2, 17) or to gradually lose viability at the high seed moisture content associated with treatment (7).

A means of capitalizing on the beneficial effects of long stratification periods would be fall sowing, thus allowing natural stratification during winter, but this practice is risky. Currently, most Fraser fir seed — much of it nonstratified — is sown in spring. To realize the benefits of cold-moist chilling,

while reducing the risks, the safest procedure for commercial growers appears to be 4 to 8 weeks of artificial stratification prior to spring planting.

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LARRY KUHNS: Did you try Clorox to control the mold growth on your seeds?

CRAIG ADKINS: *Abies* seeds are very dirty and have many different fungal organisms on them. We tried Clorox and other surface sterilants but none of them worked. A very weak concentration of Benlate will control the fungal growth.

QUESTION BOX

The Question Box Session was convened at 9:15 a.m. with Ralph Shugert and Joerg Leiss serving as moderators.

MODERATOR LEISS: What herbicides are recommended for control of perennial weeds in containers.

MICHAEL DODGE: At White Flower Farm we believe very strongly that herbicide use in herbaceous perennials is not a good practice, because of the similarity between the weeds you are killing and the plants you are growing. Good husbandry is the answer. Prevent the weeds from growing by pasteurizing the compost and preventing weeds from growing in the beds on which the pots are standing. Weeds on the standing-out beds can be controlled by using a covering cloth or a combination of Roundup and Surflan to kill and prevent weeds. Keep the surrounding area weed-free to reduce blow-in of weed seeds.

JOERG LEISS: Fusilade does a good job on grasses.

MODERATOR LEISS: Would Surflan, applied at the recommended rate during the fall, have any adverse effect on rhododendrons or azaleas planted in the spring?

LARRY KUHNS: It should have no effect even if applied in the spring after planting at the recommended rate of 2 to 4 lb AIA.

CHARLIE PARKERSON: We use this material in an EC formulation on rhododendrons and are very satisfied with it.

MODERATOR LEISS: What herbicide would you use to control wild oats and downy brome in established evergreen and deciduous nursery stock, both pre- and post-emergence?

LARRY KUHNS: For post-emergence Poast or Fusilade can be used while for pre-emergence, Surflan in spring and Devrinol in the fall can be applied.

19. Wang, B.S.P. 1960. The effects of stratification and incubation temperature on the germination of grand fir. MS thesis, Univ. of British Columbia, Vancouver, Canada.

LARRY KUHNS: Did you try Clorox to control the mold growth on your seeds?

CRAIG ADKINS: *Abies* seeds are very dirty and have many different fungal organisms on them. We tried Clorox and other surface sterilants but none of them worked. A very weak concentration of Benlate will control the fungal growth.

QUESTION BOX

The Question Box Session was convened at 9:15 a.m. with Ralph Shugert and Joerg Leiss serving as moderators.

MODERATOR LEISS: What herbicides are recommended for control of perennial weeds in containers.

MICHAEL DODGE: At White Flower Farm we believe very strongly that herbicide use in herbaceous perennials is not a good practice, because of the similarity between the weeds you are killing and the plants you are growing. Good husbandry is the answer. Prevent the weeds from growing by pasteurizing the compost and preventing weeds from growing in the beds on which the pots are standing. Weeds on the standing-out beds can be controlled by using a covering cloth or a combination of Roundup and Surflan to kill and prevent weeds. Keep the surrounding area weed-free to reduce blow-in of weed seeds.

JOERG LEISS: Fusilade does a good job on grasses.

MODERATOR LEISS: Would Surflan, applied at the recommended rate during the fall, have any adverse effect on rhododendrons or azaleas planted in the spring?

LARRY KUHNS: It should have no effect even if applied in the spring after planting at the recommended rate of 2 to 4 lb AIA.

CHARLIE PARKERSON: We use this material in an EC formulation on rhododendrons and are very satisfied with it.

MODERATOR LEISS: What herbicide would you use to control wild oats and downy brome in established evergreen and deciduous nursery stock, both pre- and post-emergence?

LARRY KUHNS: For post-emergence Poast or Fusilade can be used while for pre-emergence, Surflan in spring and Devrinol in the fall can be applied.

MODERATOR SHUGERT: What is the most economically feasible method of propagating sugar maple clones?

HARRISON FLINT: I know that they are rooting sugar maples at the Northeast Forest Experiment Station in Burlington, Vermont, by softwood cuttings.

PETER VERMEULEN: There was a paper on this by Bill Mossing.

MODERATOR SHUGERT: What are the advantages and/or disadvantages of doing hardwood evergreen cuttings in late winter (March/April) vs. November/December? How late can they be made?

CHARLIE PARKERSON: I have a paper coming out in the 1983 Proceedings (Vol. 33) and it discusses this very point. We think this is a real key. Our strongest flush of growth is the spring flush. If we make our cuttings before the buds start to swell they root and take right off.

JOHN SPARMANN: In Florida we make all our juniper cuttings in the winter months, January/February, and they take off in spring. We prefer that to summer propagation.

RON GIROUARD: In a previous paper on *Picea abies* we showed that there is a maximum rooting period in the spring (early May) with a smaller peak in the fall.

BOB GOUVEIA: We start cuttings of *Thuja*, *Taxus*, and *Juniperus* in the middle of April. The *Taxus* root in about 8 weeks but we leave them in the sand bed (on heat cables) until after the first of September. They are then transplanted. We get twice the growth compared to winter-propagated *Taxus*.

MODERATOR SHUGERT: I am having poor rooting percentages with *Syringa vulgaris* French hybrids. Can anyone help me?

CHRIS GRAHAM: At the Botanical Garden we have been rooting softwood cuttings for some time. We take our cuttings after blooming, just when the wood is turning from green to brown. We treat with No. 3 hormone powder mixed with Captan, stick them in coarse sand and peat (4:1 v/v), under intermittent mist. The rooted cuttings are left in the flats for the subsequent winter. There is tremendous variation among cultivars.

ED MEZITT: We changed our methods when we found that the white forms could not take the mist. See my paper in the Proceedings. We get about 100% rooting with our method.

PETER VERMEULEN: I would just like to support what Chris Graham said and add that water is very critical. We root

in outdoor beds and one year we had excessive rain which caused defoliation.

CARL ORNDORFF: I have reported that propagation by shoot cuttings is the hard way. The simple way is root cuttings stuck in December/January in a cool house (just above freezing). By June you have 12 to 15 in. plants. For the majority of lilac cultivars you have saleable plants in 2 years.

MODERATOR SHUGERT: When and what hormone is used for the rooting of *Arctostaphylos*? What medium is best for growing on?

JIM CROSS: I can only speak for *Arctostaphylos uva-ursi*. The harder the wood and the better drained the medium the better stands we get. Take the hardest and shortest cuttings from the center of the plant in the winter. I don't think the nature of the growing-on medium is important as long as it is well drained. I think that the severity of the changes in the environment from propagation bench to growing-on is very important. I would suggest lifting cuttings out of the propagation bench, pruning both the top and bottom, placing back in the propagation bench, and allowing them to adjust for about 2 weeks. When potting-up take a little of the propagation medium, which presumably contains some mycorrhizal fungi by that time.

BRUCE BRIGGS: To add to Jim's comments, mycorrhizae seem to be very important. You can improve rooting by grinding up rooted *Arctostaphylos* and watering it into the rooting flats.

PETER VERMEULEN: I can back up what Jim said about good drainage. We left rooted cuttings in the rooting medium too long and we lost the crop when they got too wet. We advise getting them out of the medium as soon as possible.

MIKE DODGE: We have been testing a hybrid *Arctostaphylos* from Colorado. It roots very well in the fall (October through December) using a peat/sand or peat/perlite medium with mist or in a tent. After rooting we pot them up in a pine bark, peat moss, and perlite medium (60:30:10, v/v).

MODERATOR LEISS: Our *Viburnum opulus* 'Compactum' produced from cuttings are very slow and erratic in their nursery growth. It takes 4 to 5 years to produce a decent plant. What is wrong?

CLAYTON FULLER: I think that if one watches fertility the plant would perform very nicely in a container with rapid growth. Also, you need to watch for spider mites.

MODERATOR LEISS: What, if any, work has been done with IBA in transplant gels to initiate root regeneration in difficult-to-root species?

CAMERON SMITH: We have been using Hormex No. 3 on *Dirca palustris* and get good root regeneration.

MODERATOR LEISS: I would like to know if there is any method, other than layering, that can be used to propagate filberts?

JOERG LEISS: Very soft cuttings can be rooted. Probably you will have to put your plants into the greenhouse to stimulate growth. If you wait too long the cuttings will root but the buds will fall off.

(Ed. Note — See the hot callusing grafting method for filberts developed in Oregon by Harry Lagerstedt, as described in Hartmann and Kester, 4th ed., p. 430).

MODERATOR LEISS: Has anyone micropropagated any *Acer* species? Can cultures be stored below freezing?

BRUCE BRIGGS: The problem appears to be in the production of too much callus.

DICK ZIMMERMAN: Microplant Nursery in Oregon, I believe, has done one cultivar of maple on a commercial scale. Cultures can be stored at 34 to 36°F for up to a year, as with azalea cultures.

MODERATOR SHUGERT: What is the secret to producing true-to-life variegated hostas by micropropagation? Are variegated forms produced from vegetative buds more stable than flower buds?

CHARLES HEUSER: In propagation studies with *Hosta* 'Francis Williams' we obtained three forms when vegetative buds were used.I suspect that adventitious buds were forming in tissue culture.

MICHAEL MARCOTRIGIANO: Many of the hostas are periclinal chimeras and any time that you get adventitious shoots you will lose the stability. Axilliary shoots and normal divisions are the only method of propagation.

JOERG LEISS: In England they just slice the buds into 4 lengthwise sections and get very rapid propagation.

MODERATOR SHUGERT: Does tissue culture eliminate all viruses?

DICK ZIMMERMAN: No. It can be used to eliminate viruses but that technique is different.

MODERATOR SHUGERT: What experiences have nurserymen had with heat stress in containers? What can be done to prevent it?

DICK WOLFF: We had thousands of Japanese maples this summer in the open and the heat was devastating this year (1983). We went two ways: (1) cover the plants with 52% shade cloth; and (2) syringe the plants each day at 11:00 a.m. and 2:30 p.m. for about 10 minutes.

JOHN SPARMANN: We used 2 or 3 short irrigation cycles on sensitive plants to help with heat stress.

RAY BLEW: We had a problem in south New Jersey. We turned our water lines on at 10:00 a.m. and 2:00 p.m. for 10 minutes. Two other factors should be considered. (1) You can pull the containers in tight and then spread them out as they grow. (2) Use bigger liners and get them out earlier. This has been most important with us. The plants will shade themselves and eliminate most of the problems.

MODERATOR SHUGERT: Where can I purchase Wood's Rooting Compound?

RALPH SHUGERT: Contact your local agricultural supply house or Ed Wood, who is a member of the Western Region.

MODERATOR LEISS: Question for Jack Alexander. Can *Pieris* × 'Millstream' be grafted?

JACK ALEXANDER: I have had limited success grafting onto unrooted *P. japonicum* cuttings. The work was somewhat late and perhaps earlier grafting would be better.

MODERATOR LEISS: Can *Ilex verticullata* cuttings be successfully stuck in early December?

ELWIN ORTON: I have stuck cutting of *I. verticillata* × *I. serrata* hybrids, and *I. verticillata* that time of year and they root well. Double wound the cuttings and treat them with Hormodin No. 3 and use bottom heat.

MODERATOR SHUGERT: What is the difference between *Pyrus calleryana* 'Select' and 'Chanticleer'

RALPH SHUGERT: They are the same.

COMPUTERS — WHERE ARE YOU?

WILLIAM R. STUDEBAKER

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As you probably realized, this title really asks two questions: (1) What is the state of art? What is out there today? and (2) Where are each of you today and where are you headed in relation to computers? This article discusses the 1st question and gives some guidelines to use as you may attempt to answer the 2nd question.

I would like, first of all, to share with you where our firm is today in relation to computers — where we are headed and why — as an example of another nursery to whom you can relate.

Studebaker Nurseries has had a *Basic Four Model 600* for about 7 years. (We upgraded from a *Model 400* and increased capacity during that period.) It has 48 KB of memory and 20 MB on-line disc storage and currently operates 4 terminals. It has served us well, but:

1. Technology in computers has greatly improved over this period of time.
2. The older hardware and dust in our environment causes too much downtime.
3. We need to expand our capacity for on-line storage and for processing time, and we need to increase the numberof terminals from 4 to 8.
4. We have used a band-aid approach to program changes and add-ons over the years, and our programs need to be restructured.

Therefore, we are about to upgrade probably to a *Basic Four Model 8010* with 1.5 MB main memory (1.5 million bytes compared to our current 48 thousand bytes), 144 MB on-line disc storage (compared to 20 MB currently) and 8 terminals. We will be able to take advantage of the state of the art operating system and add the following: *IDOL DBM* software, *Spread Sheet Software, Integrated Word Processing, A Security Sytem, Virtual Memory* (computer automatically utilizes disc space if it runs out), *Dynamic Disc Allocation* (computer controls placement of data files and keeps track of their location which is more efficient when designing programs and eliminates errors in program runs due to insufficient memory.)

Currently, our computer is not used a lot strictly for propagation. That department does get the budget vs. actual reports for each expense item that they control and they get their labor reports (hourly and salaried hours and dollars projected vs. actual by work code or function). We do propagate 420,000 evergreen cuttings in the winter, root 230,000 summer softwood cuttings under mist, bud 6,500 trees, and graft 1,200 evergreens — but, propagation takes a backseat to the rest of the company when it comes to number crunching.

For example, our propagation department has a maximum of 1 million items on inventory at a given time during the year while there are 2 million on inventory in the finished production areas. Propagation deals with about 150 combinations of cultivars and sizes, while the rest of the company deals with 4,500. Finally, propagation labor hours are only 3% of those of the rest of the company, thus there are fewer people to process through payroll and costing. We would have done more for propagation on the computer, but we have had limited resources with our present configuration primarily: programming time, available memory, and user terminal time available.

When we upgrade, we will develop more propagation programs. Some examples would be in the areas of: (1) Historical and current records of rooting percentage by cultivar, by category, with various analyses and trends. (2) Projections of numbers going into and coming out of each propagation phase. (3) Costing. (4) Space requirement. (5) Timing and scheduling.

Enough on introductions — we will now consider computer *systems integrators*. In a *Business Week* article this past summer, and in an article in the August, 1983, issue of *Computer Decisions*, the concept of *systems integrators* was discussed. This is being forecast as the newest need in business/computer personnel — someone to make sure that all the different systems and subsystems from all the different vendors work together efficiently. It involves integrating micros, minis, and main frames and different levels of programming languages (those of you with micros that have purchased different boards and computers and software from different vendors know about compatibility problems). I will try to fill the role of integrator a little as we consider briefly the uses and concepts in hardware and software and of sources of help, information, and experience sharing.

The most important thing in choosing hardware is to find a good reliable local vendor that services the hardware he sells (unless that brand is serviced by a local outlet of a good service organization) and provides software support. This combination is not easy to find in a vendor.

A hardware concept you should be familiar with is *micro computer* vs. *mini computer*. When a dealer is discussing a piece of hardware, it is very important that you know which it is (just ask him). Many times the size of the main memory is the same or larger on a micro as compared to a mini, but:

1. The micro cannot access or process all that memory at one time like the mini can.
2. The micro disc access time is much slower than the mini.
3. In general, disc storage is much smaller, or it takes more drives, to get the same amount of storage on a micro as compared to a mini.
4. The micro's operating systems uses much more of the memory than does the minis.

The net effect is that the micro cannot hold as much data, its programs cannot be as long and complex, and it takes much longer to process or run each program as compared to the mini. However, micros are much cheaper (approximately $10,000 to $20,000 vs. $25,000 to $100,000).

Another term or concept with which to be familiar with is *Data Base Management (DBM)*. This is either *firmware* (on a chip) or *software*. This feature allows easier report generation with limited programming. You can get your data out in many different combinations very easily without having stored the data in that form.

We will consider briefly four types of software: 1. canned or off the shelf, 2. custom designed, 3. spread sheets, 4. word processing.

With *canned programs*, you adjust to it. You conform your operating practices to match the steps and the order of the software package. These are cheaper than customed designed and for the most part have been debugged. They are quite useful for functions that are standardized across different industries. Usually payroll, accounts payable, accounts receivable, and general ledger canned programs are quite useful.

Custom designed programs are more flexible and are conformed to the way you presently operate. You do not have to change procedures. The software is bent to your specific needs. However, this is more costly. It is usually necessary, however, to get good inventory, order processing, sales analysis and costing software.

Spread sheets (like Super Calc, Visi-Calc) require no programming knowledge to be able to customize reports and financial analysis. It is especially useful for budgets, production

records and projections, propagation records and projections, and financial planning. This is a very important management tool.

Word processing is something that most of you would want as a software addition to your computer rather than as a stand alone system. It is a real time saver when used to update catalogs and manuals, to personalize mailing lists and multiple correspondence, and to prepare charts and reports.

Networking, another current computer buzzword, simply means linking together several micros to a mini. Each has its own data base which can be shared with each other or with a larger mini. This could be an interim step between a micro and a mini if your firm is not rapidly expanding, or does not need the capacity of a mini, but needs several work stations that can share data. However, a network uses a lot of throughput time if users are interacting a lot and this does not lend itself well to practical expansion.

The final concept to discuss is *time sharing*, which is basically renting time from a larger machine of another company. This is done over a phone line. This might be the most inexpensive alternative if you had large data bases and did not need frequent interaction, although security of data could be a problem. I know of at least one large nursery firm that is renting time to other users. One added advantage with this arrangement within the industry is that many of the programs could be pertinent to your own operation.

I will close by discussing sources and resources for further information. I have found magazines to be the best information source if you can take the time to read them. It is like reading the *American Nurseryman*, their ads are as informative as their articles. Following are several magazines with which I am personally familiar:

1. *Personal Computing* — one of the best for micros.
2. *Personal Software* — discusses pros and cons of available software for games, home and business use for micros.
3. *Byte* — has reader service cards you can send in for information about particular ads.
4. *Computer Decisions* — Administrative and office oriented.
5. User Group Publications:
   (a) *Association of Computer Users* — excellent for micros.

(b) *Data Stream International* — pick operating systems on minis

(c) *Pragma* — pick operating systems on minis.

(d) *PC* — IBM's micro user group.

6. *Software Center* — software catalog from a supply house.
7. *Technology Network* — used equipment dealer publication.

Other nurseries are a good source of information. The American Association of Nurseryman has a listing of nurseries available by state showing the type of nursery, type of computer and programs they have, and if they are willing to share information. It is 2 years old now, but still very helpful.

Computer "consultants" are available. I put *consultants* in quotes because they all have a vested interest (like insurance "consultants"). Even when they can 'get you any product', their recommendations will be biased by commission rates, the ease they have in dealing with the manufacturer, how the hardware relates to software they may want to sell, etc. They can be of use, you just have to weigh their input and *you* have to make the final decision.

Two excellent books that I would recommend if you own a micro or are considering buying one are "How to Select Your Small Computer — Without Frustration," and "How to Manage Your Small Computer — Without Frustration". Both are available from the Association of Computer Users in Boulder, Colorado.

Finally, if you are looking for software you can use software catalogs (which I mentioned earlier). They are the cheapest way but get out of date quickly. Or you can use personal search services. Several companies are available which do this now. They are expensive, but good if you are looking for something very unique or specific.

We have touched briefly on some of the current computer concepts and their relationship to a nursery or propagation business and on some of the sources of information on hardware and software. I would be happy to share any additional information that I have if you just contact me.

BILL SCHWARTZ: One comment. You did not talk about reliability at all. Every so often one of the machines drops dead and it needs to be fixed. This is very important and it should tell you which one to buy.

WILLIAM STUDEBAKER: That is a good point. You also need to backup every day because some day you are going to have your data wiped out.

CAMERON SMITH: One thing that I have seen many small businesses get in trouble with is the lack of fully documented software. Anyone considering custom software, no matter how minor the change from stock, should be well documented. See a good CPA firm.

WILLIAM STUDEBAKER: That is a very good point. It is very difficult to get that from a programmer.

PETER VERMEULEN: For a multifaceted use, such as office procedure, propagation, etc, would we be better to go with a mini or several micro computers?

WILLIAM STUDEBAKER: I am not sure if I can answer that question right off. It depends on if you have a large data base and a lot of interaction going on in your business. If a lot of your people will use the same data all the time then you need a mini. If you have stand alone functions then micros will work.

RALPH SHUGERT: I would just like to echo a comment you made on sharing. Zelenka Nursery is involved in sharing and feels very comfortable with that format.

WATER QUALITY IN PLANT PROPAGATION

D. BURKE McNEILL
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Vineland Station
Ontario, Canada L0R 2E0

Most propagators, I believe, do not really think about water except that they have a sufficient amount to do the job. The most important factors seem to be an adequate supply and that it is sufficiently clean to prevent clogging of nozzles in the greenhouse.

Also, in the past, I believe that life was simpler, most nurseries were off by themselves, or they were on city water and most water supplies were naturally clean. Many often used cisterns to collect rainwater which was, in those days, considered to be as clean as you could get. However, today with urbanization, industrialization, extensive use of herbicides, shortages of water in some areas, and increased costs of city water, propagators need alternate sources such as ponds

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Also, in the past, I believe that life was simpler, most nurseries were off by themselves, or they were on city water and most water supplies were naturally clean. Many often used cisterns to collect rainwater which was, in those days, considered to be as clean as you could get. However, today with urbanization, industrialization, extensive use of herbicides, shortages of water in some areas, and increased costs of city water, propagators need alternate sources such as ponds

and wells for water supply. Therefore, concern for good quality water for use in propagation has become increasingly important.

Acid rain, herbicide runoff, algae control, mineral content, etc. are all factors that have to be considered when using natural, untreated water in confined areas such as propagation benches. These factors likely would not be a problem when watering stock in the field.

When I started searching the literature for information on water quality I drew a blank. What did prompt the need for the search was a problem that arose with one of the propagators I work with in Ontario.

Being located in an urbanized area, water was readily available from the city, but the increasing cost prompted the grower to dig a well as an alternate supply. They were fortunate to hit an adequate supply of water and thought their problems were solved. The grower is an excellent propagator, but during the first winter of use of the water from the new well, they suddenly noticed their losses were greater than usual. The mystery was added to when one of their employees, who had a small greenhouse, volunteered to propagate some of the material for them and his losses, using the same cutting material, were negligible. Following a great deal of soul-searching and by the process of elimination, it was decided that the water might be the factor that was affecting the losses. Upon checking both water samples at a commercial water treating firm, and at the University of Guelph Greenhouse Soil Testing Laboratory, very high levels of sodium were found in the well water. With the addition of some very expensive filtration equipment the problem was solved.

When it was suggested that I present this paper, I felt that I needed more evidence to substantiate this particular problem and learn if there might be problems with other elements. After much looking and asking questions, it was pointed out to me that there was an article on this subject in Vol. 18 of the IPPS Proceedings. This paper, presented to the Western Region meeting by J. L. Paul (1) provided the answers. Paul reported on the effects of sodium, magnesium, and total salts on the rooting of chrysanthemums under mist. I do not intend to discuss this paper in any depth as some of the work required further study. However, it was demonstrated that total salts and magnesium and sodium levels did affect rooting and high levels were very detrimental.

Whitcomb (2) reiterated this same information in his publication on propagation. He suggested that generally chlorinated city water and water from deep wells which are low in

total salts and boron levels, are to be preferred to lake, stream, or pond water in propagation houses.

These references were the only ones that I found referring to water quality but I am sure that a serious literature search would turn up more. I am convinced that this lack of information probably stems from the lack of problems reported for poor water quality. Most of the problems I have encountered in propagation as a crop advisor have been diagnosed as too much water or poor drainage in the benches. However, from now on I will be asking more questions on water sources, for some of these problems may be related to poor water quality as well. Also, if I do nothing else today, maybe I will stimulate someone at the research level to take a further look at the problems that can be caused by poor water quality in propagation.

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2. Whitcomb, C. 1978. Propagating woody plants from cuttings. Okla. State Univ. Bul. No. 733.

RALPH SHUGERT: Have you found any information on high pH water and propagation of plants or subsequent establishment?

BURKE McNEIL: I have heard of no problems even with a pH of 8. In containers it is a problem but that is all I am aware of. It would be a good research problem.

PETER ORUM: It should be standard practice for any good nurseryman to have his water analysed several times each year. I can give you an example of what happened to a well known nursery in Europe that almost destroyed it. They did it only once a year and during a dry summer the city kicked in auxilliary wells that contained more sodium and they were not aware of it. Sodium built up to the point that their container crop was almost destroyed.

DICK WOLFF: I nearly went bankrupt using city water. We were propagating rhododendrons and maples outdoors without any problems. In the greenhouse, however, something was wrong. We traced it to the water which had a pH of 8.3 to 8.5. We dug a well with pH of 6.1 and the difference was like day and night. The township people told us they put out high pH water because the pipes do not rust as fast.

RAY MALEIKE: We had a grower who had a problem with high pH water and the accummulation of white deposits. He cured it simply by putting magnets around his intake. I don't know what it does but it sure cleared up the problem. I will be glad to send you the info if you want it.

MIKE DODGE: We had a problem with salts and high pH during our propagation. Dr. Paul Read in an article on the rooting of 'Northern Lights' azaleas suggested either injecting a small quantity of acid or rooting in a poly tent. Since we went to a poly tent for rooting our Exbury azaleas we do not have that problem.

INFLUENCE OF WILLOW AND POPLAR EXTRACTS ON ROOTING CUTTINGS[1,2]

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Abstract. Crude water extracts were prepared from shoots (1 g freeze-dried powder/25 ml H_2O) of weeping willow (*Salix alba* var. *tristis*) or of lombardy poplar (*Populus nigra* 'Italica') collected at intervals during the year. Extracts from both species or combinations of extracts + 5,000 or 20,000 mg/liter IBA inhibited rooting of *Cotoneaster acutifolius* cuttings. In comparison with water-treated (control) cuttings, cuttings of both *Philadelphus coronarius* 'Aureus' and *Ribes alpinum* (but not *Cornus alba* 'Argenteo-marginata') showed consistently better rooting after treatment with seasonal willow extracts.

INTRODUCTION

Plant extracts of diverse species have been known to influence rooting of cuttings. Went (24) observed that *Acalypha* leaf extract induced rooting in *Carica* cuttings. Bouillenne and Went (2) found in cotyledons, leaves, and buds substance(s), given the name "rhizocaline", which stimulated rooting. Nelson (20) showed that alfalfa extract contained an unknown active ingredient which increased the speed and rooting percentage of juniper cuttings. Girouard and Hess (7) suggested the presence of four root-promoting substances in extracts from stem cuttings of juvenile *Hedera helix*. In addition, other

[1] This work was supported by a grant to Calvin Chong from the Conseil des Recherches et Services Agricoles du Québec.
[2] Contribution No. J948.

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Abstract. Crude water extracts were prepared from shoots (1 g freeze-dried powder/25 ml H_2O) of weeping willow (*Salix alba* var. *tristis*) or of lombardy poplar (*Populus nigra* 'Italica') collected at intervals during the year. Extracts from both species or combinations of extracts + 5,000 or 20,000 mg/liter IBA inhibited rooting of *Cotoneaster acutifolius* cuttings. In comparison with water-treated (control) cuttings, cuttings of both *Philadelphus coronarius* 'Aureus' and *Ribes alpinum* (but not *Cornus alba* 'Argenteo-marginata') showed consistently better rooting after treatment with seasonal willow extracts.

INTRODUCTION

Plant extracts of diverse species have been known to influence rooting of cuttings. Went (24) observed that *Acalypha* leaf extract induced rooting in *Carica* cuttings. Bouillenne and Went (2) found in cotyledons, leaves, and buds substance(s), given the name "rhizocaline", which stimulated rooting. Nelson (20) showed that alfalfa extract contained an unknown active ingredient which increased the speed and rooting percentage of juniper cuttings. Girouard and Hess (7) suggested the presence of four root-promoting substances in extracts from stem cuttings of juvenile *Hedera helix*. In addition, other

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plant-derived rooting substances have been reported (10, 11, 12, 13). Kawase (14) found strong root-promoting substances extracted from softwood cuttings of *Salix alba* by centrifuging them with water or by shaking ground, freeze-dried stem tissue with water. As an alternative to synthetic growth regulators, the use of similar plant extracts as abundant and easily prepared, natural rooting stimulants show promise for practical application.

It is well established that time of year cuttings are taken influences rooting and large differences in rooting ability occur among species (1, 6, 9). Thus differences in the potency of plant extracts due to environmental and related effects can be expected, but there is no information with regard to the time of year when material used for making rooting promoting extracts should be harvested for best results. This study, therefore, investigated seasonal variation in potency of crude water extracts from shoots of weeping willow (*Salix alba* var. *tristis*), or of closely related lombardy poplar (*Populus nigra* 'Italica') collected at intervals during the year by testing the rooting response of certain shrub cuttings treated with these extracts.

MATERIALS AND METHODS

On November 10, 1980, and on January 12, March 30, May 1, June 13, and August 7, 1981, 20 to 45 cm terminal shoots were harvested from a 21-year-old weeping willow tree and a 45-year-old lombardy poplar tree on the campus at Macdonald College. A single tree of each species was sampled to eliminate inter-tree variation (16). Shoots were stripped of foliage (during the growing season), cut into 5 to 7 mm pieces, immediately stored in a freezer for 15 h. at −15°C in tightly-covered plastic containers, then freeze-dried. These were ground to pass through a 40-mesh wire screen and kept in tightly capped 225 g square bottles at −15°C. An aqueous slurry (crude extracts) was prepared immediately before each experiment by adding distilled water to the freeze-dried powder, as described below, and the mixture shaken (275 strokes per min) for 1 h at 4°C to reduce possible enzymatic reactions.

On June 29, 1981, the basal ends of 10 to 15 cm stem cuttings from 11-year-old *Cotoneaster acutifolius* plants were dipped for 3 min in all combinations of the following treatments: seasonal willow and poplar extracts (1 g powder/25 ml H_2O) from the 5 collection dates between November 10 and June 13, inclusive; indolebutyric acid (IBA) treatments of 0, 5,000, or 20,000 mg/liter; and all combinations of extracts and IBA treatments. The extract + IBA treatment combinations were obtained by mixing (v/v) 1 part extract (2 g/25 ml H_2O)

to 1 part of 10,000 or 40,000 mg/liter IBA dissolved in 50% ethanol. Cuttings, arranged as a 3 × 11 factorial in a randomized complete block design with 7 replications and 10 cuttings per experimental factor combination, were rooted under intermittent mist in a medium of 1 peat moss: 1 perlite (v/v) in fiber flats (18 cm long × 13 cm wide × 7 cm deep) in outdoor frames with bottom heat thermostatically set at 21°C. Factor A was IBA treatments and factor B, plant extract treatments. Data for percent rooting of cuttings, evaluated in early August, was transformed to log (percent rooting + 0.5/100.5 − percent rooting) before analysis of variance.

On August 20, 1981, 9 to 11 cm stem cuttings from 10-year-old *Philadelphus coronarius* 'Aureus', *Ribes alpinum*, and *Cornus alba* 'Argenteo-marginata' were treated similarly with willow extracts from all six collection dates or with water (control treatment), and rooted under conditions described above. The experiment was a randomized complete block design with six replications and 15 cuttings per experimental treatment. Rooting response in terms of percent rooting and root number per rooted cutting was evaluated in early October; data were not transformed before analysis of variance.

RESULTS

Increase in the rooting response of *Cotoneaster* cuttings was associated with increasing IBA concentrations, i.e. 25, 50, and 70% after treatment with 0, 5,000 and 20,000 mg/liter IBA, respectively (Figure 1). However, rooting in this species was markedly suppressed by both willow and poplar extracts (five collection dates between November and June) regardless of IBA treatment; the effect of plant extracts due to date of collection was variable (Figure 1).

Cuttings of *Philadelphus* (Figure 2) and *Ribes* (Figure 3) showed somewhat similar rooting response, but *Cornus* (Figure 4) responded differently. Rooting percentage and root number per rooted cutting of *Philadelphus* and *Ribes* cuttings treated with crude willow extracts from all six collection dates between November 1980 to August 1981 was markedly higher than those of water-treated control cuttings (Figures 2 and 3); coresponding data for extract-treated cuttings of *Cornus* were not significantly different or were lower than those of control cuttings depending on collection date (Figure 4).

Unlike rooting percentage, root number for all three species showed significant effects due to collection date of the willow extracts (Figures 2, 3, 4). Although variation due to collection date differed among species, the greatest stimulation

in root numbers in cuttings of *Philadelphus* and *Ribes* notably occurred in extracts collected between November and January and between November and May, respectively.

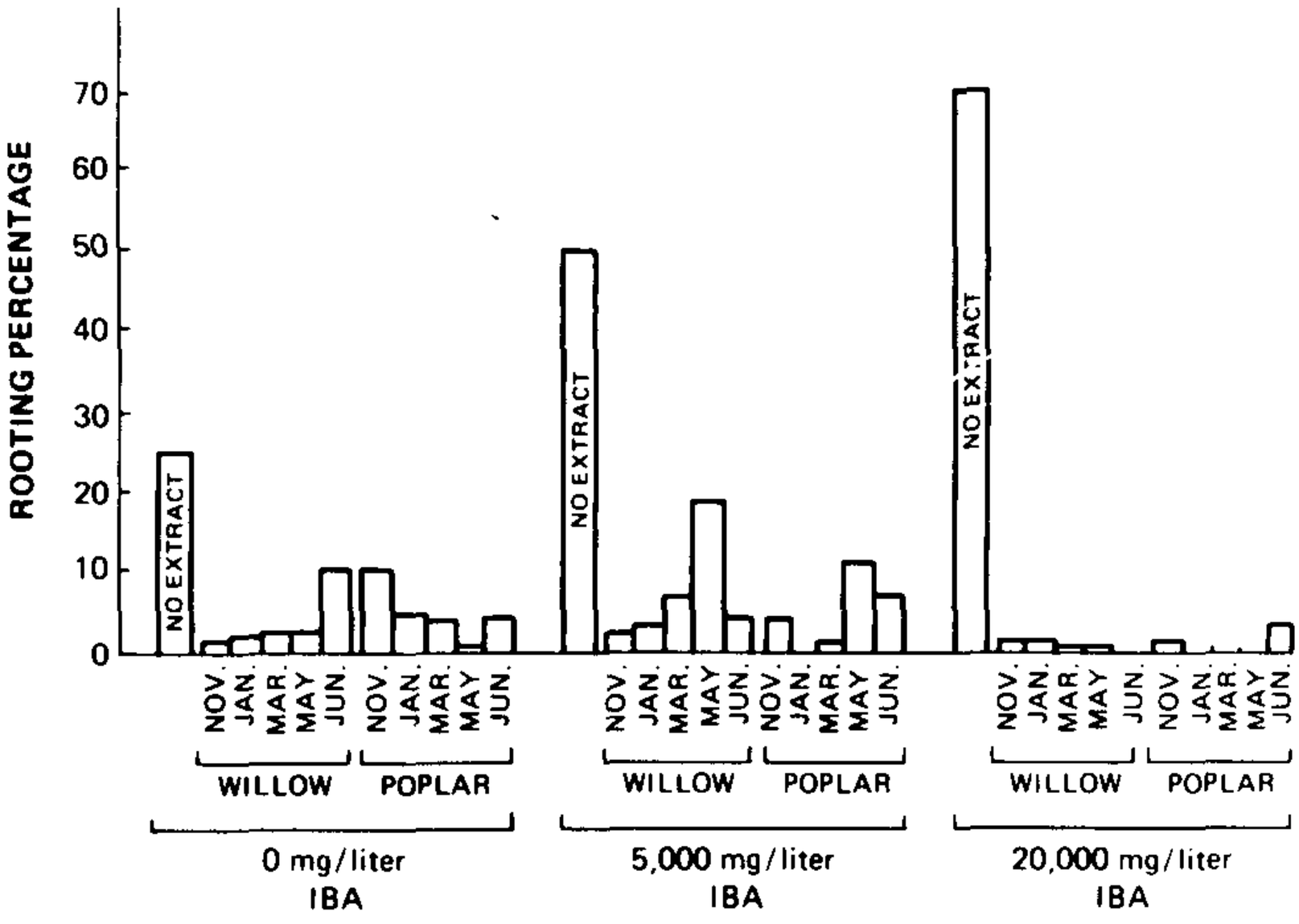

Figure 1. Rooting percentage of *Cotoneaster acutifolius* cuttings in response to seasonal willow and poplar extracts with or without IBA.

DISCUSSION

Philadelphus, *Ribes*, and *Cornus* are genera that usually root from cuttings with relative ease, especially during the early growing season. In this study, started in later summer, when rooting may be more difficult, the use of willow extracts resulted in markedly enhanced rooting of *Philadelphus* and *Ribes* cuttings but had little effect on cuttings of *Cornus*; the seasonal influence of the extracts was small. On the contrary, rooting of *Cotoneaster* was suppressed by seasonal extracts of both willow and poplar. This evidence suggests interactive and(or) complex action of plant extracts on rooting response. The similarity of influence on rooting of extracts from willow and poplar suggests that the rooting substance(s) present in both species are of similar identity.

Evidence suggests that, like other growth processes, each step of the rooting process is influenced by a delicate balance of growth regulators or other rooting substances, rather than by a single substance (17, 23). This, in part, may explain the more favorable rooting response of *Philadelphus* and *Ribes* from extracts collected in fall and winter when plant tissues have a greater amount of growth inhibitors (10). Perhaps the extracts did not contain the specific cofactors to promote root-

ing in Cornus or, possibly, the appropriate hormonal balance for root promotion was disturbed. Root inhibition of easy-to-root *Salix babylonica*, *Amorpha fruticosa*, and *Robinia pseudoacacia*, after treatments with water extracts from difficult-to-root *Castanea crenata*, *Pinus densiflora*, *Myrica rubra* and *Cryptomeria japonica*, was apparently due to the presence of growth inhibitors in the aqueous extracts (5).

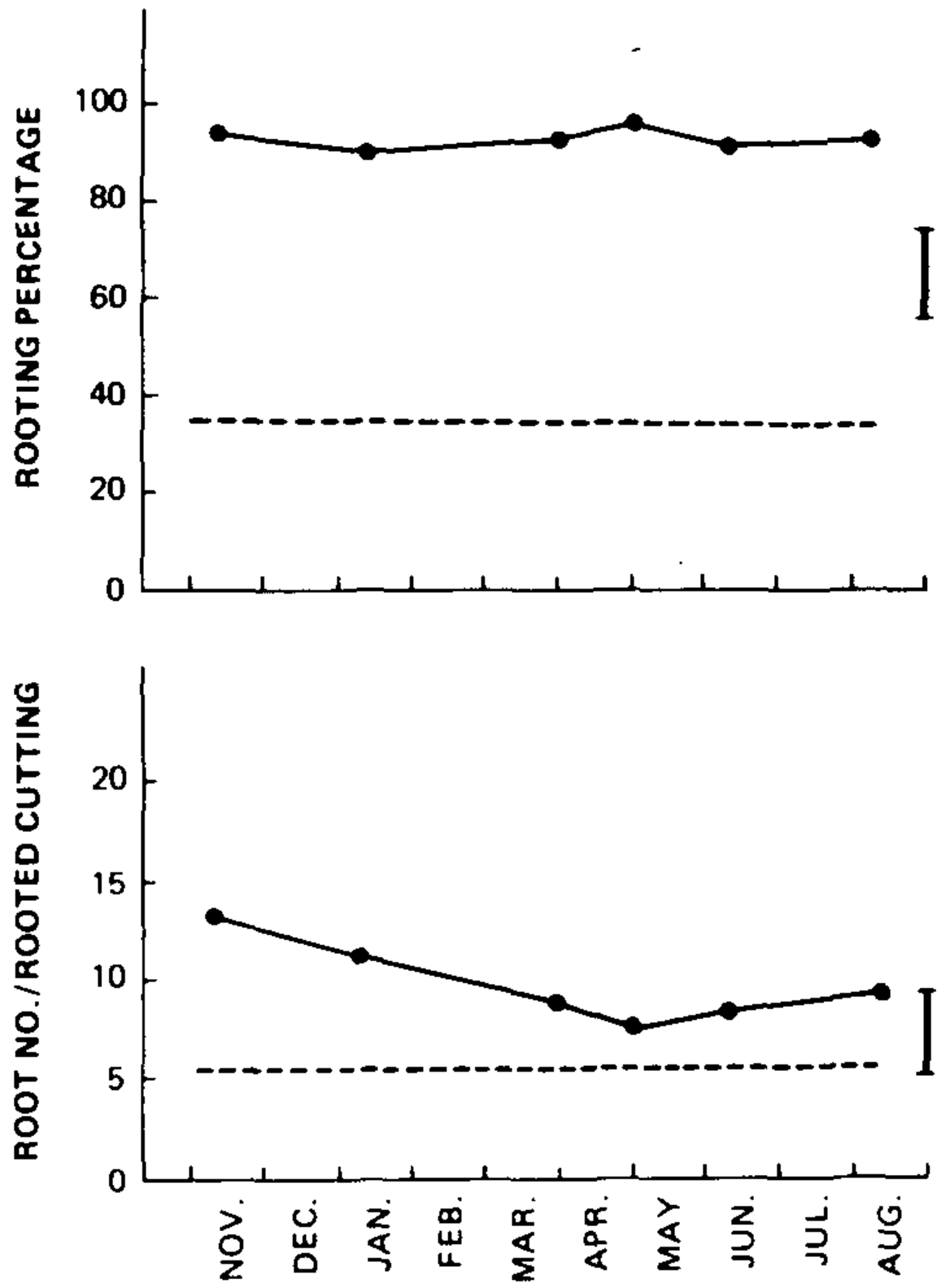

Figure 2. Rooting performance of *Philadelphus coronarius* 'Aureus' in response to seasonal willow extracts. ----- represents water-treated *cuttings*; ——— *represents extract-treated cuttings*. Vertical bars represents LSD ($P = 0.05$).

High IBA concentrations between 10,000 and 40,000 mg/liter have been shown to be a significant factor in the successful rooting of certain difficult species (3, 4). In some of these species, including *Cotoneaster acutifolius*, the base of cuttings tended to be injured by treatments with 20,000 and 40,000 mg/liter IBA although very prolific rooting occurred above the injured portion (4). In the present study, it is noteworthy that the percentage of dead *Cotoneaster* cuttings (ranging from 23 to 100%) was very high for those treated with all plant extracts + IBA combinations, compared with those treated with either plant extract, or with IBA alone (ranging from 0 to 1.7%). Thimann (22) indicated that crude plant extracts were frequently toxic.

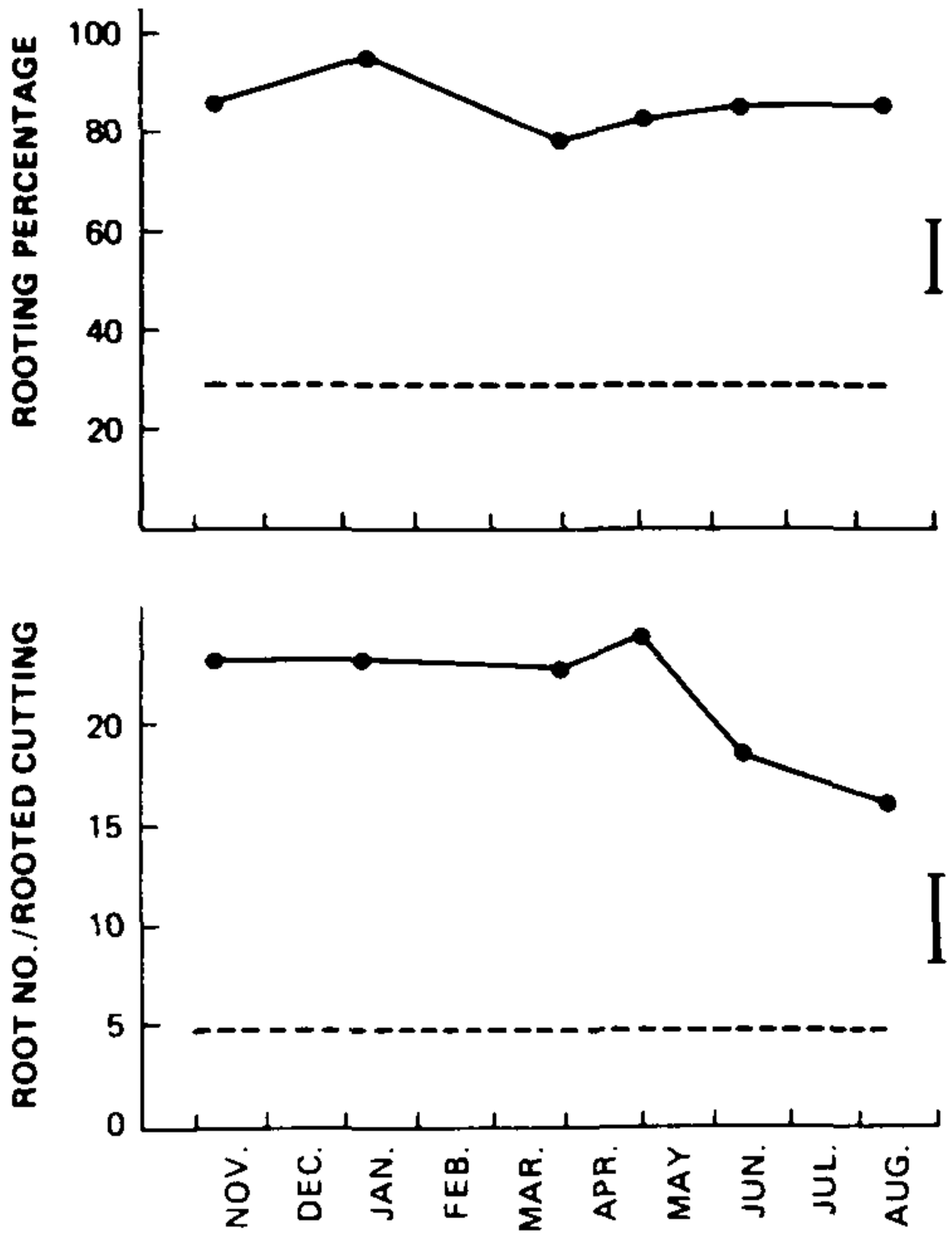

Figure. 3. Rooting performance of *Ribes alpinum* in response to seasonal willow extracts. ----- represents water-treated cuttings; ——— represents extract-treated cuttings. Vertical bars represent LSD ($P = 0.05$).

In preliminary attempts to gain a better understanding of the nature of these plant extracts, the seasonal willow samples were analysed for their carbohydrate and phenol contents. Although these substances are known to influence rooting (8, 18, 19) results of correlation of the amounts of these constituents with rooting response in *Philadelphus*, *Ribes*, and *Cornus* were inconclusive. Ouellet (21) found that boiled water extracts of barley and oat seeds and of ground pieces of *Ulmus* twigs promoted rooting of *Ulmus americana* cuttings, but these extracts were less effective than IBA. Kawase (15) reported that the centrifugal diffusate or water extract of willow showed a strong synergistic effect with indoleacetic acid in the rooting of mung beans, and contained at least four rooting fractions, the most active being very soluble in water but insoluble in chloroform or ethyl ether. Apparently similar rooting substances have been found in a variety of other woody species, including *Cotoneaster racemiflorus* var. *soongoricus*, *Euonymus fortunei* 'Carrierei', *Symplocos paniculata*,

Lonicera maackii, *Ilex opaca*, *Physocarpus amurensis*, *Taxus cuspidata*, and *Viburnum* × *burkwoodii* (16). Although the rooting substance(s) in willow was thought to be similar in effect to "rhizocaline" (15), the identity of these substances is still unknown.

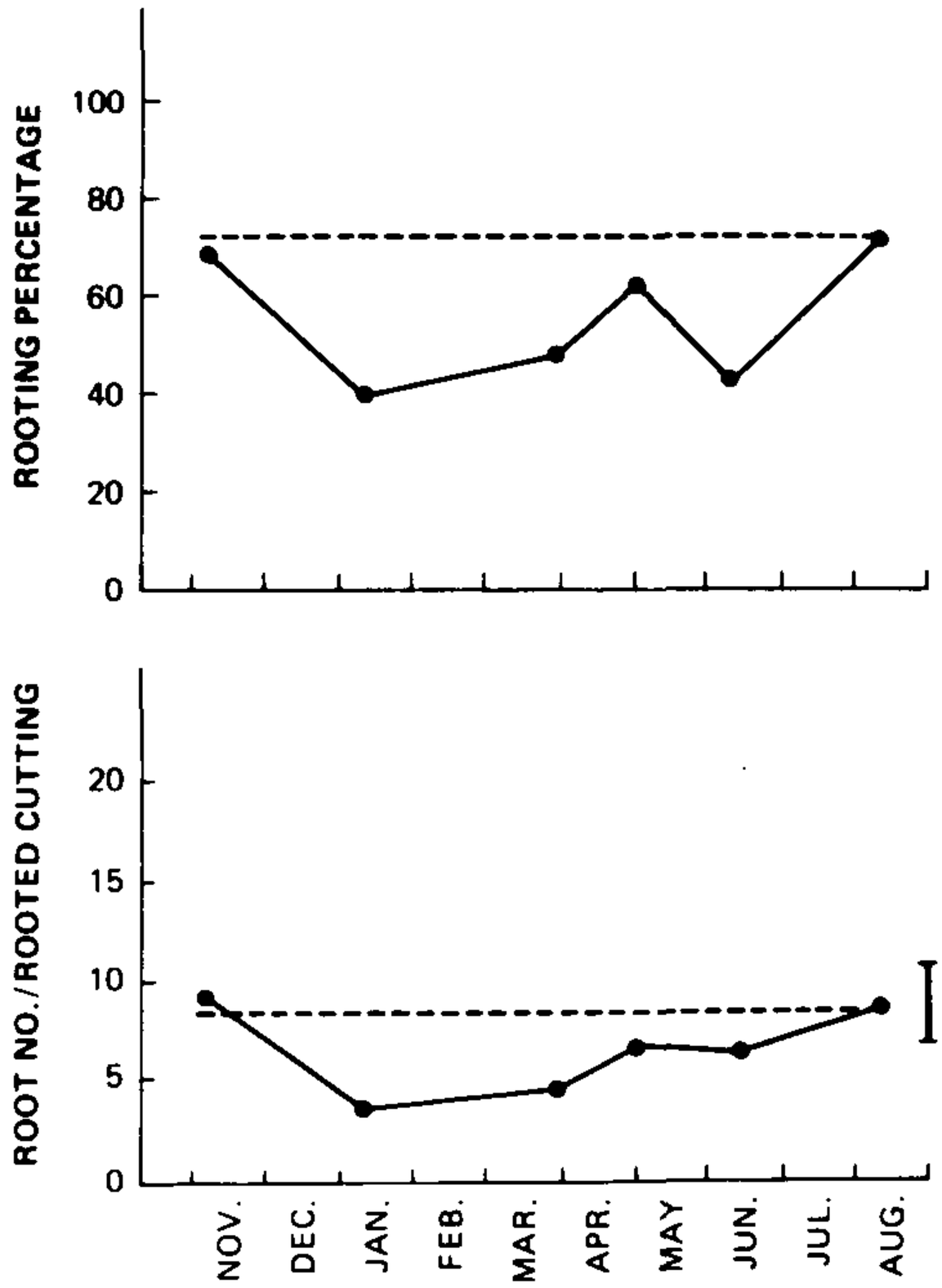

Figure 4. Rooting performance of *Cornus alba* 'Argenteo-marginata' in response to seasonal willow extracts. ----- represents water-treated cuttings; ———— represents extract-treated cuttings. Vertical bars for rooted number per rooted cutting represents LSD ($P = 0.05$); data for rooting percentage was not significant.

The evidence of this study confirms the favorable use of plant extracts, such as willow, for stimulating rooting of certain species and indicates that extracts from material collected in fall and winter may be slightly more effective in inducing rooting in cuttings of two species. However, under certain circumstances these extracts may inhibit or have little or no influence on rooting and can even be detrimental to cuttings. Studies to elucidate the identity of the rooting substance(s) in these extracts should greatly enhance their value as rooting aids.

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VOICE: Have you tried saligin, which is found in willows? If not, you should try it.

CALVIN CHONG: No, we have not.

COMPARATIVE EFFECTS OF SELECTED ROOTING COMPOUNDS ON THE ROOTING OF *PHOTINIA* × *FRASERI*

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Athens, Georgia 30602

Many commercial root promoting compounds have been offered to the nursery industry since the introduction of indolebutyric acid (IBA) and naphthaleneacetic acid (NAA) in 1935 (7). IBA and NAA form the chemical bases for these commercial preparations which are offered as talc, organic or water-based formulations (3). Many nurserymen make their own preparation by purchasing pure IBA or NAA crystals and dissolving them in an appropriate solvent (usually alcohol). Dip 'N Grow and Wood's Rooting Compound are liquid-based commercial formulations that are becoming more common in commercial propagation. Dip 'N Grow contains 1.00% IBA and 0.5% NAA plus an anti-pathogen agent in an alcohol solvent. Wood's contains approximately the same IBA and NAA but uses a solvent-carrier (20% dimethylformamide) and 80% ethyl alcohol.

This study compared the relative effectiveness of Dip 'N Grow, Wood's, and Hormodin #2 against the pure chemicals using *Photinia* × *fraseri* as the test plant. *Photinia* × *fraseri* is an excellent test plant for rooting studies because without an exogenous root promoting agent it shows limited propensity to root (1,2,4).

MATERIALS AND METHODS

Four to six-inch long terminal cuttings of *Photinia* × *fraseri* were collected from 6 to 8-year-old plants growing on the

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MATERIALS AND METHODS

Four to six-inch long terminal cuttings of *Photinia* × *fraseri* were collected from 6 to 8-year-old plants growing on the

University of Georgia campus, Athens, Georgia, on August 26, 1983. Mature cuttings (no red growth apparent) were used. The leaves from the basal half of the cuttings were removed, the end recut, then they were dipped to a depth of 1 in. in the materials (except Hormodin #2) as shown in Table 1. Cuttings were placed in a 2 perlite:1 sphagnum peat (v/v) medium in 10 cm deep flats. Thirty cuttings per treatment constituted the experimental unit. Mist was controlled by a Mist-A-Matic unit (E.C. Geiger, Harleyville, PA.) The entire experiment was conducted in a greenhouse with approximately 28°C/20°C day/night temperatures and natural photoperiod. The experiment was terminated on September 30, 1983, and the rooting percentage, number and length of roots determined. Only roots longer than 2 mm were counted.

RESULTS AND DISCUSSION

Rooting was dramatically affected by the treatments from a low of 0 percent in the water control to 100% with Dip 'N Grow (Table 2). The three control treatments (water, 50% ethanol, and water plus boron) did not stimulate rooting. This agrees with previous work (1,2,4) which showed that a rooting hormone was essential for rooting of this species. Chloromone-treated cuttings rooted only 17%. Chloromone is a mysterious rooting agent, the exact composition of which is not known (3). Obviously, it does not contain appreciable quantities of either IBA or NAA, two compounds that promoted reasonably good rooting of *Photinia* × *fraseri*.

Naphthaleneacetamide is a component of Rootone hormone powders and resulted in 67% rooting and reasonable root number and length. In the mung bean bioassay, it results in many small roots that do not elongate to any degree.

Perhaps the most striking result occurred with Hormodin #2 (0.3% IBA in talc). Rooting was only 3% with an average length of one centimeter. In all cases the liquid preparations, whether in water, alcohol, or dimethyl formamide, were superior to the talc formulation. The difference in response can be explained by the low solubility of IBA. In a talc formulation the IBA must first go into solution before being absorbed into the cutting. Rapid absorption of IBA did not occur from the talc source compared to the liquid formulations.

NAA was more effective than KNAA (potassium salt). NAA was dissolved in 50% ethanol while the KNAA was dissolved in water. The alcohol acts as an effective carrier and penetrant thus facilitating increased movement of the hormone into the cuttings. The same trend was observed with

IBA and KIBA. Interestingly, NAA and KNAA were superior to IBA and KIBA in promoting rooting of *Photinia*.

Table 1. Composition of treatments used for the *Photinia* × *fraseri* rooting study.

Treatment	Growth regulator and concentration	Solvent
Water	—	Water (Distilled-deionized in all cases)
Ethanol	—	Water (50% ethanol)
Water + 50 ppm B	50 ppm B from H_3BO_4	Water
Chloromone	? (5:1 dilution)	Water
Naphthaleneacetamide	Naphthaleneacetamide (0.3%)	50% ethanol
Hormodin #2	Indolebutyric acid (0.3%)	Talc
NAA	∝naphthaleneacetic acid (0.3%)	50% ethanol
KNAA	Potassium salt of ∝naphthaleneacetic acid (0.3%)	Water
IBA	Indolebutyric acid (0.3%)	50% ethanol
KIBA	Potassium salt of indolebutyric acid (0.3%)	Water
KIBA + 50 ppm B	Potassium salt of indolebutyric acid (0.3%) + 50 ppm B from H_3BO_4	Water
IBA + NAA	Indolebutyric acid (0.2%) Naphthaleneacetic acid (0.1%)	50% ethanol
KIBA + NAA	Potassium salt of indolebutyric acid (0.2%) Potassium salt of naphthaleneacetic acid (0.1%)	Water
Wood's	Diluted 5:1 Indolebutyric acid (0.2%) Naphthaleneacetic acid (0.1%) 4% Dimethylformamide	Water
Dip 'N Grow	Diluted 5:1 Indolebutyric acid Naphthaleneacetic acid	Water

KIBA plus boron (B) was particularly effective in stimulating rooting. I have observed this response with other plants. It is suspected that B serves as a carrier or at least facilitates transport of molecules. The B would hasten the movement of IBA into the cutting. Boron, when included with exogenously applied growth regulators, increases the translocation of these compounds (5,6).

Table 2. The effects of selected rooting compounds on the rooting percentage, root number, and root length of *Photinia* × *fraseri* stem cuttings.

Treatment	Root parameters		
	Percent	Number	Length
Water	0	0	0
Ethanol (50%)	7	0	0
Water + 50 ppm B	3	0	0
Chloromone	17	1	5
Naphthaleneacetamide	67	6	28
Hormodin #2 (0.3% IBA)	3	0	1
NAA	87	11	59
KNAA	53	5	30
IBA	63	7	46
KIBA	33	2	8
KIBA + 50 ppm B	83	8	47
IBA + NAA	83	8	47
KIBA + KNAA	23	2	10
Wood's	97	26	116
Dip 'N Grow	100	24	151

The IBA + NAA treatment resulted in 83% rooting while the KIBA + KNAA-treated rooted 23%. The 50% alcohol solvent apparently facilitated auxin movement into the stem tissue. The K-salts of IBA and NAA are as effective as the acids (7). The limiting factor may be the rate of absorption into the stem tissue.

Cuttings treated with Wood's and Dip 'N Grow rooted 97 and 100%, respectively, and had the greatest root numbers and root lengths compared to other treatments. Both were diluted 1:5 which resulted in 0.2% IBA and 0.1% NAA in the treatment solution. The IBA + NAA and KIBA + KNAA treatments contained the same amount of active ingredients (auxins). The only difference was the solvent system. Logically, it must be concluded that the solvent system (carrier) can have a pronounced effect on the effectiveness of a rooting compound. The carrier facilitates rapid absorption of the rooting compound and a more uniform response.

Previous work (1,4) has shown that *Photinia* × *fraseri* roots maximally when treated with 0.5 to 1.0% IBA applied as a concentrated dip. In this study the 0.3% IBA in 50% alcohol, or 0.2% IBA + 0.1% NAA in 50% alcohol was not sufficient to induce 95 to 100% rooting. However, these same levels in a different solvent system (Wood's, Dip 'N Grow) did result in 97 and 100% rooting. By using an appropriate solvent, the effect of the IBA is enhanced. This means that lower levels of the rooting compounds can be used.

Dimethyl formamide is a powerful solvent and care must be exercised in its use. It is considered a universal solvent and is used to dissolve nylon and other synthetic fibers.

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SELECTION AND PROPAGATION OF CRAPE MYRTLE

DAVID BYERS

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What plant other than my favorite, *Lagerstroemia indica*, blooms about 100 days most years, in a color range from deep red to pink, lavender, and white? Name another that has such beautiful fall colors and outstanding bark characteristics and grows in so many different sizes and forms. Crape myrtle is truly one of the world's best and most adaptable plants.

Found originally in China, *Lagerstroemia* was named by Linnaeus in 1759 to honor his friend, Magnus von Lagerstroem, a naturalist who was a director of the Swedish East Indies Company. Late in the 18th century, crape myrtle was brought to this country, and George Washington was an early admirer and collector.

Many, many selections have been made throughout the years. The ones described herein are favorites that we have grown and seen flourish across the southern U.S. for years. This information is based on observations and is not the result of scholarly work or well-designed experimentation. Because crape myrtle is subject to problems of climate, producers in other areas will disagree wtih these evaluations at times.

There is no shortage of excellent red cultivars. Each part of the South seems to have its own.

'Regal Red' crape myrtle is a seedling selection made by my father, Marcus Byers in the late 1960's. The flower color is deep red, one of the darkest of all. A broader grower, 'Regal Red' is not as tall as some but is a fine choice for the profusion of flowers that are showy from late July until frost. Adequately winter hardy, it is moderately resistant to powdery mildew.

'William Toovey' is an old selection, made by Howell Nursery Company in 1927. It has a pinkish-red flower, sometimes called watermelon red, and is a very heavy bloomer. Usually its height is about 12 ft., and the habit of growth is broad and spreading.

'Byers Standard Red' has a fine rose-red bloom. An old-time favorite, this is our tallest growing and best tree form red cultivar.

'Victor' is a cadillac crape myrtle. It is a compact, bright red cultivar that grows to about 3 ft high and wide. When planted in large masses, they give the appearance of 'Hino-crimson' azaleas in bloom all summer long. Red stems and

buds add to this effect. 'Victor' is one of the hardiest crape myrtle cultivars we have seen.

'Tuscarora' is a red selection from a cross of *L. indica* × *L. fauriei* 'Basham's Party Pink' × *L. indica* 'Cherokee'. It was introduced by the U.S. National Arboretum, Washington, D.C., in 1980 and is said to be highly mildew-resistant. This plant was featured in full color on the cover of the "American Nurseryman" magazine and is in strong demand at this time. Although it is still new with us, I have some concern about its ability to stand very cold weather. Other red cultivars worth mentioning are 'Carolina Beauty', 'Dallas Red', and 'Okmulgee'. 'Cherokee' is an introduction of the U.S. National Arboretum and apparently is an excellent plant, but it has been confused in the trade from the start, and I hesitate to recommend it.

There are many good crape myrtles in other colors, too.

'Byers Wonderful White' is another of my father's long-ago selections. Its upright form and clear white, basketball-size flower clusters make this the standard white cultivar in the South. This is the most winter-hardy crape myrtle we have seen. A very tall grower, it exhibits yellow fall leaf colors.

'Natchez' is one of the best choices to come from the breeding work at the U.S. National Arboretum. It is a very vigorous grower with lots of medium-sized white flowers and high resistance to mildew. 'Natchez' originated in 1964 from a cross of *L. indica* and *L. fauriei*. As a result of the *L. fauriei* influence, a spectacular feature is the exfoliating dark cinnamon-brown trunk bark. Dr. Egolf gets an A+ for 'Natchez'.

'Near East' is an introduction of Overlook Nurseries of Mobile, Alabama. The shell-pink flowers are beautiful. They appear usually a few weeks later than most crape myrtle and the plant seems to be less than vigorous. It exhibits a bushy form and is less hardy then most. 'Near East' is featured at Callaway Gardens in Georgia.

'Potomac' is my favorite of all crape myrtles. The upright form and heavy caliper make this the perfect tree crape myrtle. Clear pink flowers, much like 'Coral Belle' azalea blooms, are early and abundant. It was introduced in 1967 by the U.S. National Arboretum.

'Conestoga' is one more fine plant from the U.S. National Arboretum work. Its gracefully arching limbs have a tough job to support the large tapered pale pinkish-lavender flowers. 'Conestoga' grows about 10 ft. high and 12 ft. wide.

'Seminole' blooms profusely with lovely medium red-pink flowers and grows to only about 8 ft. I think the trade has yet

to realize how good this U.S. National Arboretum choice really is.

'Basham's Party Pink' is another hybrid of *L. indica* and *L. fauriei* and has the expected vigor and bark characteristics. This chance seedling was found in Texas and introduced by Lynn Lowery in 1965. Lots of lavender-pink flowers, large spreading habit, and questionable hardiness are qualities of this crape myrtle.

'Catawba' and 'Powhatan' are two more of the Indian-named choices made by the U.S. National Arboretum. Both are mildew resistant, with lavender flowers, ('Catawba' is a bit darker), and are relatively hardy. They grow to about 10 ft. and have excellent fall color. I think a combination of 'Catawba' and 'Conestoga' in a planting is a stunning sight.

'Byers Hardy Lavender' is an old crape myrtle and one of the best tree-form selections we have. Flowers appear later than most others, but continue to be effective until a hard frost ends the display.

'Muskogee', a U.S. National Arboretum selection is again a hybrid with *L. fauriei*. Light lavender flowers and the pretty bark are outstanding features. It is fast growing and highly mildew resistant.

Crape myrtles are easily propagated by either softwood or hardwood cuttings. Our primary effort is with wood taken after frost. The wood is sawed into 8-inch cuttings, graded, bunched, and stored over winter. The cuttings are planted into the open field in March, spaced 2 to 3 in. in the row with 2 in. above the ground. Surflan is applied following sticking. They are irrigated as needed all summer long. A 4-in. cutting of 'Natchez' will grow to 3 ft. in one summer on drip irrigation.

In July we cut them back to make them thicken. A U-shaped blade is run under the plants to check and harden them in October.

Defoliation, caused by the first hard frost, signals time for harvest. Some cultivars do not defoliate readily, which means that we must contend with the problem of drying leaves in storage. It would obviously be better if defoliation occured while the plants were still in the field.

We have worked closely with Dr. Charles Gilliam, Auburn University, in testing various chemicals that might defoliate the plants safely and effectively. The most satisfactory was an ethylene-type material. When applied 2 weeks before the first hard frost, it gave good results. However, the problem is how to predict the first frost accurately.

The procedure we find most consistently satisfactory is the old-fashioned technique of sweating off the leaves. We dig the plants after frost whether or not they have defoliated. Those that have not are piled in the warehouse and watered thoroughly several times. Heat builds up and the leaves drop. When the plants are pulled from the pile, any remaining leaves shake off easily. They are then processed in the usual way. We sell half a million crape myrtles per year, mostly as liners.

'Victor' and other dwarf cultivars do not produce enough long shoots to fit our hardwood program. Consequently these are rooted under mist in peat pots using very soft cuttings. Dilute solutions of IBA seem to aid and speed the rooting response. Cuttings are usually taken in July and in a few weeks are ready to move to the field.

Propagation by seed is not recommended because of the wide array of variations that result. There are enough choices, covering the entire range of shapes, sizes and colors readily available, to make this endeavor unproductive.

There are just too many variables for any one person to be an expert on crape myrtle, and my evaluations are, of course, subjective. Your own thoughts and experiences can add greatly to their usefulness. The *Lagerstroemia Handbook/Checklist*, in the reference list, is invaluable. It can be obtained from the author, Box 206, Swathmore, PA 19081.

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HEMEROCALLIS PRODUCTION AND CULTIVATION

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Since 1979 we have changed our production of daylilies to a year-round approach. We divide our daylilies during any month in the year, except when they are blooming. The demand for our daylilies has surpassed our quantity grown. We retain enough stock plants to redivide individually. Our plants are then cut back to half their matured height and spaced on 12-in. centers in the drill on 38-in. row spacing. We utilize this spacing because our farming equipment is set for 38-in. spacing — planters, cultivators, harvest equipment, and sprayers.

Weed control. After a block of daylilies is planted, I use a rolling cultivator to plow up a 3- to 4-in. wedge on the drill. I then apply the herbicide Lasso 4 EC (alachlor) over the entire bed and middle at the rate of 2 gal./A Lasso 4 EC (8 lbs. a.i./A), using 85 gal./A of water. In Florida, Monsanto recommends post-emergence application of this chemical because of our sandy soil composition. We repeat this spraying every 65 days. This controls our crabgrass problems throughout the growing season.

Cultivation. Herbicides do not control all weeds in our daylily blocks; therefore, we have resorted to a more practical way to eliminate the broadleaf weeds and grasses that our herbicides miss or do not suppress. Although it seems drastic, it works.

During the month of July we use a pasture mower. The mower is set to shave ½ in. of the soil surface, leaving a bare surface with nothing but the daylily stubble at ground level. The area between the rows is mowed at approximate 3 in. We then use a hay rake, or finger rake, to rake the residue to the skip-middle. This residue we leave for 1 or 2 weeks. It is then burned in the field. After finger raking the field we utilize a rolling cultivator to rework the middle and plow ½ in. of soil back over the top of our daylilies. We then apply Lasso 4 EC again at the rate of 8 lbs. a.i./A. This procedure has eliminated all of our costly hoe labor.

PROPAGATION AND CULTIVATION OF *PRUNUS LAUROCERASUS* 'SCHIPKAENSIS'

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The species, *Prunus laurocerasus*, or English laurel, is native to southeastern Europe and Asia Minor and has been known in cultivation since 1576. It is a large, wide-spreading evergreen shrub growing 10 ft. tall or more, with a spread up to twice that. It is a medium-textured plant with medium to dark green leaves, which lose some of their luster in cold climates. The leaves are alternate, simple, and about ⅓ as wide as long. The leaves may be as long as 6 inches, and are obscurely serrate to nearly entire. The ¼ in. white flowers are borne in 5-in. long racemes in April to May and are unpleasantly fragrant. The fruit is a round purple to black drupe ⅕ to ½-in. long. The fruit is often lost among the foliage.

Prunus laurocerasus is a medium-fast grower capable of attaining 10 ft. in 5 to 6 years under favorable conditions. It is hardy to Zone 6. This species and its cultivars are shade tolerant and withstand pruning quite well. They are relatively easy to transplant balled and burlapped or from containers. Compared to its cultivars, 'Schipkaensis', 'Zabeliana', and 'Otto Luyken', *Prunus laurocerasus* is large, coarser, and less susceptible to some disease problems.

The cultivar 'Schipkaensis' derives its name from its place of origin, Shipka Pass in Bulgaria. Like the species, it usually grows wider than tall. It may grow to 10 ft. but is usually seen in the 4 to 6 ft. range. It also is a medium-textured plant with medium to dark green leaves about ⅓ as wide as long. Leaf length is 2 to 4½ in. The leaves may be entire but some always have some serration — a point which distinguishes 'Schipkaensis' from 'Zabeliana'. Flowering and fruiting has been observed to be sparse.

Schip laurel may grow over 12 in. in a year but is usually slower. Hardy to Zone 5, it maintains good foliage color through cold weather. It has been grown on Hilton Head Island and does quite well in Macon, Georgia. Schip laurel takes well to pruning, but when started as a bushy plant, no pruning is needed.

Why is schip laurel so popular? We have already mentioned its hardiness, adaptability to pruning, good foliage color through the winter, and shade tolerance. Shade is not necessary but may be an advantage in container culture to help

keep roots cool. Another main factor is that other evergreens in its size category — several of the *Ilex* cultivars, and junipers, euonymous cultivars, and dwarf Burford holly — have been overused, in the author's opinion, and schip laurel provides an alternative. Schip laurel does not look formal or manufactured; it is informal and natural-looking in many situations. Its texture and dark foliage color makes it useful in combination with other plants. Schip laurel makes an excellent foil for light colored plant material like sycamore or birch trunks, and variegated liriope. Furthermore, established in the landscape, it is a relatively low-maintenance plant.

Prunus laurocerasus 'Zabeliana', or Zabel laurel, was introduced into the nursery trade in Europe about the turn of the century. Like 'Schipkaensis', it is smaller and more refined than the species. Zabel is more spreading than schip laurel. Dirr (1) reports plants 5 ft. tall and 25 ft. broad. Proportions of 3 ft. high and 6 ft. spread are common. This spreading habit may not be evident under shaded or crowded conditions. Zabel and schip laurel are easily confused. Typically, Zabel laurel leaves are more slender; they are always smooth-edged, while most leaves on a schip laurel show some serration. Schip and Zabel laurel mixed together in mass plantings are indistinguishable from a distance and obviously different only to an informed observer at a close distance. Unlike 'Schipkaensis', Zabel laurel is free-flowering. It also has a Zone 5 hardiness rating.

'Otto Luyken' laurel was introduced by a German nursery in 1968. It is the smallest, most compact of the cultivars under discussion. It may grow 3 to 4 ft. tall with a 6 to 8-ft. spread, but does not attain this size rapidly. 'Otto Luyken's' leaves are typically 3 to 4 in. long and 1 in. wide. It is quite floriferous, even in the shade. The author is unsure of this cultivar's hardiness. Because of its dark green color and compact habit, 'Otto Luyken' is becoming very popular.

Propagation of schip laurel is not difficult. Semi-hard to hardened terminal growth will root any time of year. Fastest results will be obtained during the summer when the new growth has hardened to the point that it snaps when bent. Although no controlled tests comparing media or rooting stimulators have been made, success with sand, perlite, sterilized sandy topsoil, and pine bark has been observed. The use of a root stimulator promoted faster, more profuse rooting. No special procedures are necessary to root schip laurel, but sanitation and preventive sprays are required to produce healthy material consistently. It is not necessary to strip or wound the cuttings.

Two procedures for rooting schip laurel have been highly successful. One involves taking 4- to 6-in. semi-hardened cuttings from June through September, treating them with a fungicide dip in 16% Manzate (maneb) at 1 tbsp/gal. and then a quick dip in a solution of 0.2% IBA and 0.1% NAA in alcohol. The cuttings are stuck under intermittent mist. Root formation may be observed in as little as 3 weeks, with most cuttings ready to be hardened off in 3 to 4 more weeks.

With the second method, cuttings are made of the current season's growth from September through November. These also are immersed in a broad-spectrum fungicide, like Captan or a Benlate (benomyl)-Manzate combination. These hardened cuttings get the same IBA-NAA quick dip. Cuttings are stuck in a fumigated ground bed of well-drained sandy loam and wet down thoroughly. The bed is covered with plastic stretched over wire hoops, the edges of the plastic are buried to seal in moisture and warmth, and shade is provided by a cover of Saran 50% shade cloth. No mist is applied. Maintenance consists of regular moisture checks and monthly fungicide sprays. Because of the time of the year rooting is much slower. By spring the cuttings are rooted and may be transplanted or left to grow on in the bed for a season. When left undisturbed in a ground bed, schip laurel may put on 6 to 9 in. of growth in a summer. Naturally, pruning to induce branching is preferable.

Schip laurel is very marketable and easy to propagate. However, it can prove frustrating to produce a high-quality plant to sell, especially in container production. There are several potential problems, but the most serious are root-rot and shot-hole disease.

As with other *Prunus* species, good soil aeration is a must for schip laurel. Deep planting in a container or the ground will result in poor performance or death. *Prunus laurocerasus* and its cultivars are not tolerant of overwatering.

Shot-hole disease is self-descriptive. It is seldom fatal but can easily ruin the appearance of a plant. With a mild case, a few round holes might be easily overlooked. But shot-hole can progress until a majority of leaf tissue is damaged, and the result is most unsightly. Shot-hole was once thought to be a fungus disease but is known now to be a bacterial problem. One group of causal organisms is certain *Xanthomonas* species. Plants under frequent overhead irrigation suffer shot-hole much more readily than unirrigated or occasionally-irrigated plants. Some growers have stopped container production of schip laurel and turned entirely to field production for this reason.

There are steps to take to try to avoid problems with shot-hole disease on schip laurel. Minimize free moisture on the foliage by adequate spacing and by watering early enough to allow leaves to dry before nightfall. Maintain a regular preventive spray program with a material that is effective against bacterial organisms.

It is not unusual to have problems with shot-hole even after doing everything practical to avoid it. It is not unusual for the disease to appear suddenly in a finished crop of plants. It is not unusual to have problems with shot-hole worse on one cultivar one year, and worse on another the next year. No one cultivar seems more resistant than another.

Another problem encountered on schip laurel is peach scale, which attacks the stems and is easily overlooked. This pest can be disastrous. Recommended treatments are oil emulsion sprays during the mild spring and fall months, and Cygon or Malathion according to label instructions during the summer.

They are also susceptible to damage from spider mites and tent caterpillars. Both of these pests may be prevented or killed by standard sprays.

If one is careful, and with luck to avoid disease and insect problems, schip laurel is not a demanding plant. Usually pruning while young to encourage branching yields full, shapely plants. Slightly acid soil is best. Schip laurel has no peculiar nutritional demands; it is reputedly not a heavy feeder and is not prone to iron chlorosis or other similar problems, yet it responds well to fertilization. Schip laurel is not hard to transplant. It does not grow well in a container during very hot conditions, but this is true of many other ornamentals.

Once established in the landscape in well-aerated soil and protected from severe drought, the *Prunus laurocerasus* cultivars are attractive, low-maintenance plants. They offer designers hardy, dark green, medium-textured evergreens in a very useful size category. They are highly marketable and easy to propagate. Schip laurel is commonly field-grown with good success. The challenge lies in container culture, where close attention to water, correct potting, situations favorable for shot-hole disease, and good luck are necessary for success.

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GRAFTING OF JAPANESE MAPLE CULTIVARS

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Japanese maples have been used in the Orient for more than 300 years. They can no longer be brought here directly from Japan but must be sent to Korea or Holland for growing on, then sent here. They are one of the most diverse groups of all ornamental plants. Within the group can be found close to 300 cultivars. Forms range from dwarf to upright, cutleaf to palmate, and variegated to many other unusual characteristics. Also, outstanding spring and fall coloration is an added feature among this group of plants. Some have red or green bark or exfoliating bark. The most serious cultural problem is leaf scorch, which is a physiological reaction to water stress. They are extremely sensitive under high light conditions. There is an excellent reference by J.D. Vertrees (1).

Grafting of Japanese maples begins in early January. The well-established understock is allowed to go completely dormant before being brought into the greenhouse in December. The plants are then sorted and placed in benches according to whether a low or tall graft will be made. The greenhouse is best positioned north and south so that the sun rotates completely across the greenhouse for optimum radiation.

Both side veneer grafts and top grafts are made according to how well the scion matches the understock. Most scions are collected the day of grafting unless we have freezing temperatures. Since most maples have a thin bark, it is important that the scions are in good condition for optimum callus formation. Of course, many scions are shipped to us from other nurseries and collectors, but we do not store any scions for prolonged periods. We use Tina knives, dipped frequently in alcohol or Benlate (benomyl). We also dip the cuttings in half-strength Orthene (acephate) to help control aphids.

The grafts are then wrapped with a rubber bud strip and coated with a black asphalt material (Treheal) applied at room temperature. We leave a narrow space on the back side, which allows for easy removal of the bud strip.

Grafts are immediately placed in the greenhouse in beds with clean sand as a stratum. The beds are provided with bottom heat as we want to keep roots growing actively. These beds are alternated with mist beds. In this way we can provide high humidity as the alternate beds mist every 30 minutes on a sunny day. We maintain 55°F or higher night temperature.

Daytime temperature may reach 85°F. We do not shade until it is extremely hot. We mark the cuttings with stakes in front of the first and behind the last plant. We write out the preferred Japanese name on the stakes. We change to metal tags when the plants are moved to the plastic house.

After the grafts have knitted and are growing, a careful check is made daily to determine if the rubber bud strip should be cut to prevent girdling. This is very important as the scions expand tremendously. A constant check is also made for suckers and aphids as they can weaken or destroy a good scion.

The grafts are allowed to remain in the greenhouse until the following fall. Some cultivars have grown in excess of 3 ft. during this period. All grafts are then moved to a plastic house for the winter.

Last year we grafted about 140 cultivars of *Acer palmatum*, plus cultivars of *Acer buergerianum*, *Acer campestre*, *Acer japonicum* and other species and their cultivars.

LITERATURE CITED

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PROPAGATION OF SHADE AND FLOWERING TREES BY CUTTINGS AT PLEASANT COVE NURSERY

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Pleasant Cove Nursery is located in Middle Tennessee where competition is keen. Since our only products are containers and balled-and-burlapped material, our customers are usually retail nurseries and landscape contractors. One of our foremost objectives is to provide our customers with a large selection. With over 140 cultivars of field stock and 100 cultivars of container-grown plants, it has become necessary to propagate many of our plants. In recent years we have expanded our propagation facilities to an annual production of over 500,000 plants. Of these, 125,000 are flowering and shade trees. We are constantly trying new selections of trees that can feasi-

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bly be rooted from softwood cuttings. Since this program was instigated, several cultivars, such as flowering dogwood (*Cornus florida*) cultivars; thundercloud purple leaf plum (*Prunus* × *blireiana*); and Yoshino cherry (*Pruus* × *yedoenis*), are produced each year with good success. This past season we had very good results with some of the red maple (*Acer rubrum*) cultivars, and several cultivars of flowering crabapple (*Malus* spp).

Preparation: All cuttings are rooted in ground-bed houses. No bottom heat is used. The rooting medium consists of approximately 60% pine bark, 30% top soil, and 10% sand. The mix is thoroughly tilled about 10 in. deep. It is then sterilized by gassing with methyl bromide at a rate of 1 lb/60 ft^2. Immediately after aeration the house is covered with clear plastic. During rooting we try to maintain a surface temperature between 95° and 100°F. (32° to 35°C). This is accomplished by applying various amounts of white paint and by cutting about five 12-in. diameter holes along the top of the house. Door openings are covered with burlap as a wind barrier and, depending upon the weather, we regulate the temperature by opening and shutting the doors.

From a propagation standpoint we segregate the dogwoods from the other flowering shade trees. Dogwoods are stuck the latter part of July, whereas all others are rooted in late May and early June. Therefore, bed preparation varies. Beds used for early cuttings are leveled and thoroughly watered; 50 lbs of Osmocote (18-6-12) are incorporated into the top 2 in. of the medium in each house at a rate of 1 lb/20 ft^2. It seems the cuttings benefit from added nutrients immediately upon rooting (3).

Dogwoods differ in that they are rooted in 2¼-in. plastic cups. After the bed is tilled, the mix is raked aside and the cups are hand placed in the bed and then filled and packed. This is done before gassing. There is no fertilizer added.

Cuttings: All cuttings are taken from young, vigorous, field-grown plants usually no older than 3 years. They are preferably taken early in the morning before it becomes hot. Cuttings taken in June are tender and very susceptible to heat. As soon as the cuttings are taken, they are placed in a large water vat and covered with Saran cloth. They are transported to the "cutting house" where they are either made or placed in cold storage until preparation. Cuttings are 5 to 8-in. long. About ⅓ are stripped; the remaining leaves are tipped and a slant cut is made at the base of the cutting. They are then washed in a Benlate solution as a disease-preventative treatment, drained, and placed in cold storge. The following morn-

ing all the plants are stuck by the cutting crew. This allows the field crew time enough to gather sufficient cutting material and all sticking is accomplished before the houses become uncomfortably hot. By using this procedure, all cuttings are taken, prepared, and stuck in a 24-hr period.

Early May and June cuttings are taken as soon as new growth is firm enough to stick. When they are taken later in maturity, rooting is not as quick or vigorous. Birch cultivars are an exception. They seem to do just as well taken 2 or 3 weeks later. All cuttings are dipped in a liquid alcohol solution of 10,000 ppm IBA. Under optimum heat, intermittent mist is set for 10 sec. at 10-min. intervals. On extremely hot afternoons it is increased to 10 sec. every 5 min. Likewise, on cool or rainy days the mist is cut back or cut off completely. Rooting usually occurs in 2 to 4 weeks. The plastic is then removed and replaced with 50% Saran. We continue with the intermittent mist for about 2 weeks, slowly cutting back the amount every few days. This prevents any shock or burn that may otherwise occur. The Saran remains for another 2 weeks. After its removal weeds are extracted and an application of Scotts Ornamental Herbicide 1 is applied.

During the growing season Sta-Green (12-6-6) Nursery Special is added 1 lb/30 ft^2 every 6 weeks. Each month a solution of either Benlate, Banrot, or captan is applied as a fungicide treatment, and Subdue is used as a drench at least once to prevent root rot. Late November the houses are covered with clear plastic for overwintering. Enough growth is attained for early transplanting the following spring, usually in February or March, before the plants break dormancy.

The procedure and care for rooting dogwoods is different as follows. Dogwoods are taken in late July and dipped in an alcohol solution of 20,000 ppm IBA. Little, if any, fertilizer is applied before winter. As described in earlier *Proceedings* by Flemer (2) and by Bauer (1), dogwoods are susceptible to winter damage. For protection we harden the young plants by exposing them to 2 or 3 light frosts. Then each of the beds is covered and sealed with a blanket of Microfilm and plastic. The house is also covered with plastic, and gas heaters are installed. These are only used on extremely cold days when the house temperature drops below 20°F (−7°C). In early spring when temperatures begin to moderate, the beds are uncovered and Sta-Green (12-6-6) is applied, as previously described, to promote early growth.

A sufficient root system and some top growth (1) must be established before dogwood can be successfully transplanted. In June the plants are uncupped, dipped in Terra-Sorb and trans-

planted. Young plants should be irrigated when necessary for the first season.

With the advancement of rooting hormones and different propagation techniques, there will be more and more breakthroughs in rooting tree species. As operating costs rise, nurserymen are constantly striving for more resourceful means of production. New ideas and the necessity of lower costs will open many doors for rooting flowering and shade trees.

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LIME AND LIME SOURCES IN CONTAINER NURSERY PRODUCTION

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The topic of lime and lime sources is one that has confronted nurserymen throughout nursery history, especially since the advent of container production in soilless and bark mixes.

In container production, the standard practice has been to add a certain quantity of lime to the mix, either for pH adjustment, or to supply calcium and magnesium, or for both reasons. There are a number of products available to growers that will fill the need when a lime source is desired (10).

It is my intention to focus on several sources of lime, the merits and disadvantages of each, and also to present some of the findings from an O.M. Scott and Sons research project this past spring.

It is important to know what calcium and magnesium are and what they do for the plant. The element calcium is required for active cell division, formation of cell walls, transport of carbohydrates and amino acids, and formation of roots.

A deficiency of calcium results in a stunted plant and restricted leaves. Some plants show a paleness at the leaf margins and curling leaves. This is most noticeable in broad-leaved plants. Three sources of calcium are:

planted. Young plants should be irrigated when necessary for the first season.

With the advancement of rooting hormones and different propagation techniques, there will be more and more breakthroughs in rooting tree species. As operating costs rise, nurserymen are constantly striving for more resourceful means of production. New ideas and the necessity of lower costs will open many doors for rooting flowering and shade trees.

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LIME AND LIME SOURCES IN CONTAINER NURSERY PRODUCTION

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The topic of lime and lime sources is one that has confronted nurserymen throughout nursery history, especially since the advent of container production in soilless and bark mixes.

In container production, the standard practice has been to add a certain quantity of lime to the mix, either for pH adjustment, or to supply calcium and magnesium, or for both reasons. There are a number of products available to growers that will fill the need when a lime source is desired (10).

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A deficiency of calcium results in a stunted plant and restricted leaves. Some plants show a paleness at the leaf margins and curling leaves. This is most noticeable in broad-leaved plants. Three sources of calcium are:

1. Calcium hydroxide ($Ca(OH)_2$), hydrated lime, is very soluble and will raise the pH rapidly. It may also be caustic to young plants and seedlings.
2. Calcium carbonate ($CaCO_3$) is the material found in ground limestone, or HiCal. It is also found in dolomitic lime. It is a safe form of lime with no caustic action.
3. Calcium sulfate ($CaSO_4$), gypsum, will add calcium without affecting the pH.

The element magnesium is one of the elements required for the production of chlorophyll. A deficiency will soon lead to a reduction in the rate of photosynthesis. It also has an effect on the transport of phosphorus.

Symptoms of magnesium deficiency generally show up in the older leaves as a light "V"-shaped margin in the leaf with the rest of the leaf remaining green. However, some plants will develop a red or bronze color on the older leaves. In fact, this condition was referred to as "bronzing disease" until it was found that a lack of magnesium was the cause (2,3,5,7). Two sources of magnesium are:

1. Epsom salts ($MgSO_4$).
2. Magnesium limestone, or magnesium carbonate ($MgCO_3$). This is the material that is found in dolomitic lime, and in dolomite. True dolomite is a substance that is mined and contains 50% calcium carbonate and 50% magnesium carbonate. Dolomitic lime contains dolomite, with some additional calcium carbonate (2,3,5,7,8).

In addition to helping satisfy the needs of the plant for these two elements, liming the potting mix performs another important function, which is the reduction in the amount of hydrogen ions. When roots grow, they give off carbon dioxide (CO_2), which combines with water and releases hydrogen. Also, when bark and organic materials break down, hydrogen ions are produced. The hydrogen not only lowers the pH but it also displaces elements on the bark and on the plant root. The hydrogen ions block the uptake of desirable elements. The calcium and magnesium displace the hydrogen and allow for the uptake of the desirable elements (6,9).

With the knowledge that both calcium and magnesium are important to the production of healthy plants, the selection of a source of those two elements becomes important.

A grower has a choice of two types of material: bulk lime or bagged lime. The bulk lime consists of calcium, limerock, and other impurities. In some parts of the country this is the same material that is the subsurface for paved interstate highways. This material does not add a great quantity of calcium

and very little magnesium. Also, it does not have a lot of staying power, hence the plants become deficient in those elements in a short period of time. The advantage of this material is that it does not cost a lot.

When selecting a brand of bagged lime, a grower has a number of sources to consider. Brands include:

1. James River Dolomitic Lime; available throughout the U.S. Southeast.
2. Docito Dolomitic Lime; available in Alabama, Mississippi, Louisiana, and Texas.
3. Hi-Cal Vitalime, and Soil Doctor; available in Florida.
4. Rockydale; available in North Carolina.
5. Reveille Dolomitic Lime; available throughout the U.S. Southeast.

A close look at the label tells a lot about the product although most of them look the same. For example:

1. The Vitalime and Soil Doctor are lower in magnesium than the others.
2. The James River Limestone has the highest magnesium content.
3. The Dolcito, James River, and Rockydale have the finest grinds.

How a grower uses dolomitic lime is also a consideration. Incorporation of lime is by far the most efficient method of achieving the full benefits from the product. The reaction of calcium and magnesium is more rapid and the altering of the pH is also faster than if the lime were applied to the surface. Also, lime that is surface-applied is expensive, not only because of the labor, but because it is slow to react (1).

The research that O.M. Scott and Sons conducted this past spring indicated that several factors were instrumental in determining the quality and suitability of the lime source used.

1. First, the degree of fineness is very important. The finer the grind of the material, the more rapid the response both in terms of availability of the elements in the lime and the response to altering pH. Fineness is measured by the percent of the material that would pass through a 100-mesh screen. A 75% rating is desirable.
2. Second, the percent of calcium carbonate and magnesium carbonate did make a difference. Specifically, when the levels of magnesium in the soil were maintained at optimum, performance was greatly improved for a majority of plants.

The Scott study involved the incorporation of several sources of lime into comemrcial potting mixes along with fertilizer and microelements. This test was conducted in Florida and used mixes that contained over 50% Florida peat. The peat had a pH in the low- to mid-4 pH range. Plant indicators tested included *Dracaena* spp, *Ixora* spp, and "reflexa".

After 6 months, these studies indicated that an increase in the amount of dolomitic lime may be necessary in order to prevent the pH of the mix from dropping out of the range where optimum plant growth can be expected. Lime rates in this type of mix of 15 to 20 lbs/yd^3 may be required. The exception to this would be in a nursery that had either high soluble salts or high sodium levels in the water. Under these conditions, the pH did not increase regardless of the source of lime; pH's were 4.7 to 4.8 at the end of six months. Also, many times when high salts or high sodium are found, high chlorine is also found. The chlorine would be detrimental to many plants. Using 15 to 20 lbs of lime per yd.^{3} in a potting mix that contained mostly pine bark, shavings, or Canadian peat would *not* be recommended, as a significant rise in pH would probably occur.

In presenting information on lime and lime sources, a complicated and involved discussion on pH could be raised. The purpose of this paper has been to point out that, regardless of the importance of pH, the fact remains that plants need adequate amounts of calcium and magnesium. A good quality dolomitic lime with 35 to 40% magnesium carbonate and 45 to 60% calcium carbonate, with 75% of the material able to pass through a 100 mesh screen, would be the most economical source of achieving that end.

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INFLUENCE OF JUVENILITY AND MATURITY IN PROPAGATION

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Importance of juvenility and maturity in propagation. Why are juvenility and maturity important in propagation? In a schematic representation of a 100 year old tree there are three zones of maturation: (1) a juvenile zone at the crown and base of the tree: (2) a transition zone; and (3) a mature zone or region (Figure 1). Any propagules taken from the base of this tree will have juvenile characteristics and be potentially easier to root, regardless of the chronological age of the propagule. The transition zone of the tree is comparable to puberty in humans with both juvenile and mature characteristics. In general, transition zone material will not flower and propagules taken from this region root less readily than juvenile material, yet more readily than mature material. The mature zone is characterized by the ability to flower and set fruit, but frequently there is a drastic reduction in rooting potential. Characteristically, a plant will not express its commercial potential until after it has reached a mature stage. Hence, as propagators we have an interest in learning to manipulate these three physiological stages of growth either to enhance rooting by causing a reversion back to the transition or juvenile condition, or to encourage earlier flowering, fruit bearing, or expression of other desirable mature characteristics by speeding up the maturation process.

Physiological condition vs. chronological age. It is the physiological condition, not the chronological age which determines a plant's capability to form adventitious roots (ARF). A sucker, which may have developed 50 years ago at the base of this 100 year old tree in the juvenile zone, will have a greater chance of rooting than a 5-month-old shoot that has recently developed in the mature region. It is the physiological age, the

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internal chemistry of the plant, that determines successful rooting.

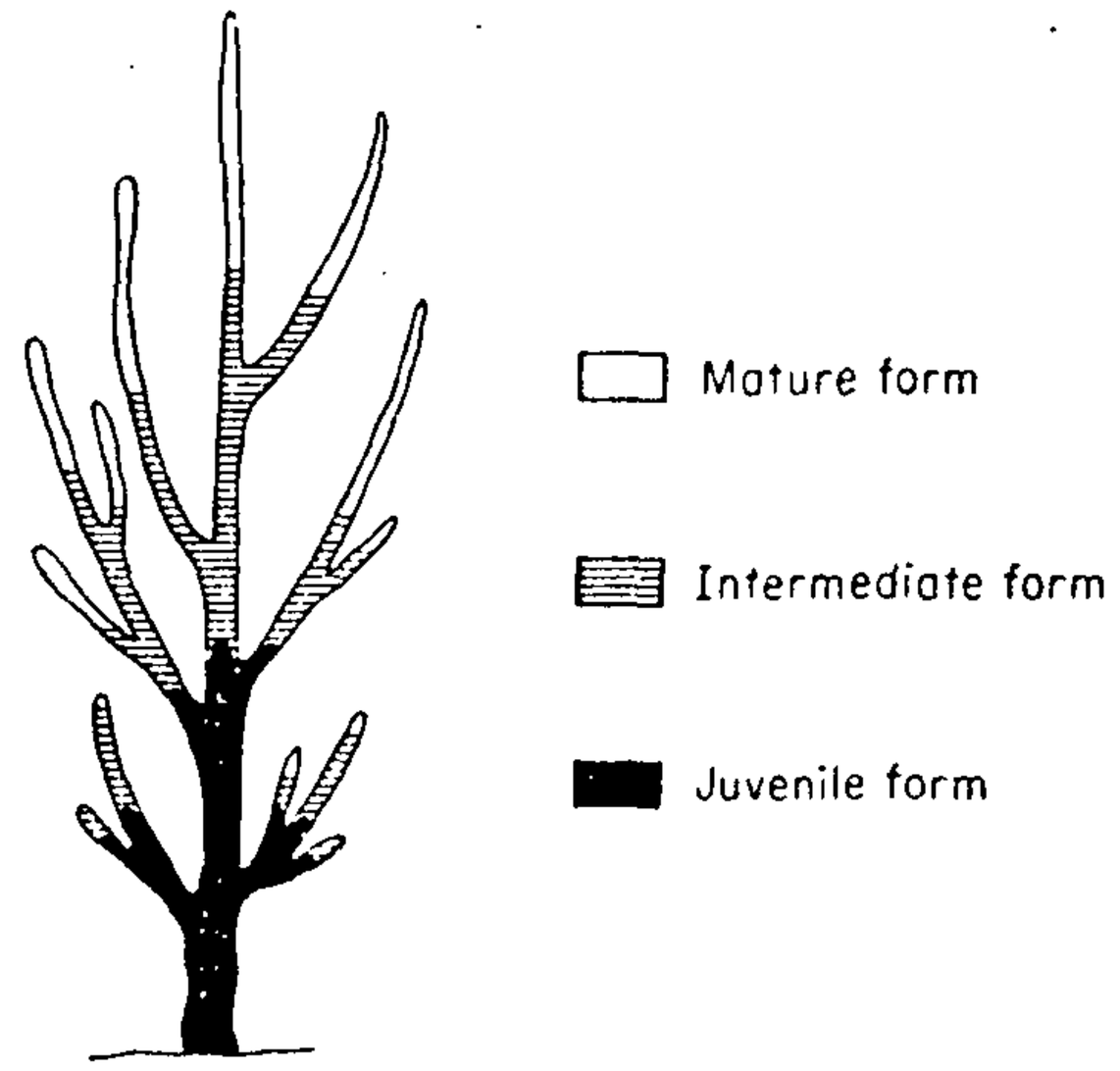

Figure 1. Schematic representation of a 100 year old tree with a juvenile, intermediate (transition) and mature zones.

Type of wood selected. There are a number of conditions, or factors, that need to be considered in the rooting of cuttings. One critical factor is the type of wood selected: hardwood, semi-hardwood, softwood, or herbaceous. Stock plant conditions are particularly important when we compare rooting between easy-to-root juvenile and difficult-to-root mature materials. Again, we are considering the physiological conditions of the stock plant such as carbohydrate/nitrogen ratio, auxin, and rooting co-factor content.

Physiological condition of stock plant and rooting. Certain plants show strong morphological (physical) differences between the juvenile easy-to-root form and the mature more difficult-to-root materials. Examples are aralia (*Dizygotheca elegantissima*) with differences in both leaf size and the number of leaflets per compound leaf; English ivy (*Hedera helix*), and creeping fig (*Ficus pumila*), with sharp differences in leaf morphology and actual plant form (shrub vs. trailing vine ground covers). Junipers are an example of a woody plant species that has mature scale-like foliage at the top and more juvenile needle-like foliage at the base of the plant.

Adventitious rooting — organized developmental process. The formation of adventitious roots (ARF) is an organized developmental process that entails sychronization of internal chemical changes and subsequent structural changes.

Structural aspects of juvenile vs. mature material. Juvenile material forms less structural material, such as sclereids and fibers, which help support the shoot system by making the tissue stronger. As a plant gets older the amount of sclereids and fibers increases since a larger and more mature plant needs greater support. Some researchers have felt that sclereids are actual physical barriers to the rooting process, hence they have tried to correlate sclereid formation with decreased root formation.

Origin of adventitious roots. Another factor is the actual origin of adventitious roots from stem cuttings. With many easy-to-root species, adventitious roots will originate from phloem ray parenchyma cells, which are located in the phloem region. The phloem is involved with transporting photosynthates such as sugars and growth regulators to other parts of the plant. In the phloem tissue there are parenchyma cells capable of undergoing cell division, which must occur for rooting to take place. The phloem region acts as a "loading zone" where sugars and metabolites can be utilized in the rooting process. Difficult-to-root plants often form roots from callus tissue. Both juvenile and mature stem cuttings will form *de novo* roots by dedifferentiating cells into meristematic zones where cells actively start to divide. Root initials are then formed, followed by root primordia. During the final stage, root primordia elongate through the stem and penetrate through the periderm. The key factor in ARF is the capability to dedifferentiate and form root primordia. It is this capability to form primordia that separates difficult vs. easy-to-root plants (2). Once primordia are formed they can exert tremendous pressure in penetrating through the stem. Only in carnation has a layer of fibers been shown to retard root elongation.

Rooting studies in mature and juvenile *Ficus pumila.* A study was done comparing ARF between juvenile and mature *Ficus pumila* (Table 1). The key difference between juvenile and mature materials was that juvenile cuttings formed roots more rapidly. However, once primordia were formed, there was a comparable time period between the elongation phase of primordia in both juvenile and mature material (7 vs. 8 days) to the point where 100% rooting occurred, indicating that it is in the early stages of rooting, that genetic capability, not the elongation of primordia that is most critical (Table 1). In growth regulator studies, 1000 mg/liter IBA-K gave optimal rooting for the juvenile and 3000 mg/liter gave optimal rooting for mature *Ficus pumila* cuttings (1). There is a 2 to 3x increase in the amount of auxin needed to get a comparable rooting response with the mature material, and even then ARF

occurs much more rapidly with juvenile material. Most likely the mature form does not have as much auxin or there may be some chemical breakdown of auxin occurring more rapidly compared with juvenile material.

Table 1. Time of adventitious root formation in juvenile and mature leaf-bud cuttings of *Ficus pumila* L. treated with IBA.

	Juvenile	Mature
Anticlinal cell divisions of ray parenchyma	day 4	day 6
Primoridia	day 6	day 10
First rooting[a]	day 7	day 20
Maximum rooting[b]	day 14	day 28

[a] Based on 25% or more cuttings with roots protruding from stem.
[b] Based on 100% rooting and maximum root number.

Auxin, other factors, competent cells. Auxin is certainly a factor. However, we know that not all plants respond to auxin, such as difficult-to-root plants. Auxin may not be the sole limiting factor determining why plants do not root. Most likely there are other chemical factors that limit rooting. Forestry researchers use the term "competent cells." Competent cells have the genetic capability to form adventitious roots. These may include phloem ray parenchyma cells or callus cells that undergo successful cell division and dedifferentiation. For successful rooting, then, there are a number of factors such as competent cells, auxins, carbohydrates, substrates for energy reactions, and cell wall formation. There are also chemical complexes. Rooting co-factors are phenolic compounds that act synergistically with auxin to enhance ARF. It is now thought that rooting co-factors form complexes with auxins and certain enzymes to enhance the rooting process.

Seasonal effects, plant age, and rooting. Seasonal effects on stock plants is another factor in comparing easy and difficult-to-root material. Increased rooting during peak seasonal periods is associated with increased cambial activity. In juvenile *Ficus pumila* the controls show a seasonal response; and when auxin is applied, the seasonal response is overcome (3). With mature, difficult-to-root *Ficus*, rooting occurs with controls only during the months of April and May, and rooting percentage is low. When auxin is applied, rooting is enhanced in the mature material, but the seasonal response is not overcome, and the winter months have much lower rooting compared to spring.

Shoot RNA and rooting. How does the shoot system influence the rooting process? Shoot RNA is part of the genetic material of a plant involved in producing proteins that act as enzymes and serve as catalysts for driving chemical reactions.

We wanted to study how shoot RNA might be involved in the rooting process. During periods of low rooting there were very low levels of shoot RNA produced (Table 2). During periods of high rooting there are much higher levels of RNA produced. Somehow, shoot RNA is involved with the rooting process. Comparing easy vs. difficult-to-root material, the juvenile has greater RNA activity than mature material.

Table 2. Relationship between shoot RNA and adventitious root formation in *Ficus pumila* cuttings.

Plant Age	Rooting Level[x]	RNA
Juvenile	High	0.801
Mature	High	0.647
Juvenile	Low	0.631
Mature	Low	0.478

[x]Shoot apicies were harvested from stock plants during high rooting months of March, April, and May and during low rooting months of November and January.

Can we fool Mother Nature? So the question comes up — can we fool Mother Nature? To a degree we can. One way is by rejuvenation, which is a key factor in the concept of manipulating a plant's physiological condition to enhance rooting. Rejuvenation is commercially done by etiolation, mounding, stooling, hedging-back. During etiolation of a stock plant, part of the plant is grown in the absence of light, which causes certain chemical and morphological changes to occur. There are commonalities between etiolation and juvenility, such as less structural tissue formed by fibers and sclereids. There are higher auxin and rooting co-factor levels. A current theory is that with reduced fiber and sclereid formation, there is less lignin formed. Consequently there may be more available metabolites for forming rooting co-factors.

Mounding and stooling are used with the Malling clonal apple understock series, with pecans, and with certain other difficult-to-root material (6). In Peru they have been able to produce clonal pecan understock by girdling and then mounding and stooling stock plants (6).

In pines and other difficult-to-root species, Hare's rooting powder, containing auxins, rooting co-factors, sugar, growth retardants and fungicides, has been developed for use in pines and other difficult-to-root species. Hare's powder is used with woody plant material that is initially girdled and air-layered before removing the cutting. A low percentage of *Quercus virginiana* propagules have been rooted using this technique.

Serial cuttage. Serial cutting propagation is another rejuvenation technique. Cuttings are initially taken from a difficult-

to-root plant. Only a small percentage will root. Those cuttings that do root are then grown on as stock plants in a greenhouse under optimal nutritional, water, and light regimes to encourage vegetative growth. Cuttings are then taken from these new greenhouse-grown rooted stock plants. Morgan (7) has had some success with *Quercus virginiana* using this technique.

Tissue culture. Another rejuvenation technique, which probably has the greatest commercial potential, is tissue culture (4, 5). With tissue culture we can take an explant from a mature, difficult-to-root species, manipulate the explant and subsequently rejuvenate mature material during the tissue culture phase to make it much more responsive to rooting techniques. The potential of working with mature material and successfully tissue culturing it is unlimited (4).

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COMPARISON OF IBA QUICK-DIPS WITH TALC FOR ROOTING CUTTINGS

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Hundreds of thousands of man-hours have been spent by nurserymen and university researchers trying to formulate the ideal rooting medium, the ultimate mist system, the best structure, and the perfect rooting compound. In fact, such a creature, or combination thereof, probably doesn't exist since there are no two nurseries that are exactly alike in all aspects. Unlike the manufacturing industries, which can produce identical products at two or more distant locations, given the same set of specifications, we deal with a rather diverse group of living systems — dynamic living systems. As proof that our plant materials are continuously undergoing subtle change, consider the new clones, sports and hybrids which "appear" in our nursery industry annually. In comparison to the manufacturing industries, our actual production sites are subjected to a multitude of environmental and other influences — heat, cold, drought, flood, air pollution, weed pressure, air and water drainage and, of course, water quality; not to mention differences in media composition or soil types, fertility programs, pest control, or management systems. It's no small wonder that each nursery is different from all others. Each of us is a person with certain peculiar characteristics, which identify us as an individual. Nurseries enjoy the same distinction. This unique agricultural industry presents some interesting challenges in that a production system that works well at your neighbor's nursery may not work at all at yours. Any successful production system in our industry has taken years of trial and error to develop — it didn't just happen. And we must be receptive to change, gradual change to continuously upgrade and improve our techniques. Do not completely revamp any part of your production system without first trying the innovations on a small scale to be certain that they will work. Let me preface the remainder of this presentation by emphasizing that this holds true for plant propagation. In our experience, we have had superior results with IBA (indole-3-butyric acid) quick dips as compared to talc formulations in rooting cuttings. If you choose to try this technique, do so on a small scale first.

In vegetative plant propagation, the specific auxin, as well as its concentration and method of application, can affect rooting of stem cuttings. Also, cultivars within a given species may

vary in their requirement for an optimum auxin concentration or method of application. And just as important as any of the above factors is the physiological condition of the cuttings at the time they are harvested, i.e., softwood, semi-hardwood, or hardwood. In essence there is a combination of factors, each of which must be exactly right if maximum rooting is to be achieved. The following studies were concerned only with the comparative efficiency of commercially-available talc or liquid rooting compounds.

Semi-hardwood terminal cuttings of southern wax myrtle were collected on 15 August. Each cutting was trimmed to 10 cm (4 in.), and leaves were removed from the basal 4 cm (1½ in.). Thirty cuttings were then subjected to each of the treatments listed in Table 1. Cuttings treated with liquid quick dip had the basal 2 cm (0.8 in.) dipped into the appropriate IBA solution, followed by 5 minutes of air drying prior to being inserted into the rooting medium. Cuttings treated with talc formulations were moistened, dipped into the appropriate talc formulation to a depth of 2.5 cm (1 in.), and gently tapped to remove excess powder. Talc-treated cuttings were dibbled in to prevent removal of powder. (Some growers have tried making a slurry of the powder. However, this adds to the cost and seems not to improve results.) Cuttings were stuck in individual 7 cm (2¾-in.) plastic rose pots containing a medium of 1 peat: 1 perlite (v/v). Pots were placed in an outdoor shaded frame (47% shade) under intermittent mist. The mist system operated for 6 sec. every 5 min. from 6 a.m. to 9 p.m.; 77 days after being stuck cuttings were harvested and data were recorded (Table 1). Cuttings treated with IBA liquid quick dip, regardless of concentration, rooted in higher percentages than those treated with talc formulations. Untreated cuttings failed to root at all. Note that both Hormodin 3 and HormoRoot 2 contain higher percentages of IBA than the 0.5% IBA quick dip, yet neither of the talc formulations was as effective in terms of percent rooting. Note also that in terms of the mean number of roots per cutting, the 1.0% and 1.5% IBA liquid quick dips were superior to the talc formulations.

Semi-hardwood cuttings 20 cm long (8 in.) of Leyland cypress were taken on 15 August and treated similarly to those of southern wax myrtle. Data from them was also recorded 77 days later (Table 2). In the case of Leyland cypress, it was felt that cuttings were not left in the propagation bed for a sufficient length of time. However, several trends are evident. With the 0.5%, 1.0% and 1.5% IBA liquid quick dips, there was a rooting response of 76.5, 86.5 and 86.5%, respectively. Compare this to the response of 40.0% for cuttings treated with

Hormodin 3 or the 56.5% rooting for cuttings treated wth HormoRoot 2. Compared to Hormodin 3, the 0.5% IBA liquid quick dip was superior for the rooting of this species even though it contained a lower percentage of active ingredient.

Table 1. Response of semi-hardwood southern wax myrtle stem cuttings to selected rooting compounds.[z]

Treatment	Percent Rooting[y]	Mean number of roots/cutting	Mean root length (mm)
Untreated	0.0 d	0.0 c	0.0 c
0.5% IBA liquid quick-dip	90.0 a	8.7 b	47.6 a
1.0% IBA liquid quick-dip	86.5 a	15.7 a	50.3 a
1.5% IBA liquid quick-dip	90.0 a	16.7 a	41.1 a
Hormodin 3 (0.8% IBA in talc)	56.5 b	2.6 bc	37.4 a
HormoRoot 2 (2.0% IBA in talc)	30.0 c	0.9 c	16.4 b

[z]Means within a column followed by the same letter are not significantly different at the 5% level - Duncans New Multiple Range Test.
[y]Each value based on 30 cuttings.

Table 2. Response of semi-hardwood stem cuttings of Leyland cypress to selected rooting compounds.[z]

Treatment	Percent rooting[y]	Mean number of roots/cutting
Untreated	53.5 bc	2.4 ab
0.5% IBA liquid quick-dip	76.5 ab	2.8 ab
1.0% IBA liquid quick-dip	86.5 a	2.9 ab
1.5% IBA liquid quick-dip	86.5 a	3.5 a
Hormodin 3 (0.8% IBA in talc)	40.0 c	1.4 b
HormoRoot 2 (2.0% IBA in talc)	56.5 abc	1.6 ab

[z]Means within a column followed by the same letter are not significantly different at the 5% level — Duncans New Multiple Range Test.
[y]Each value based on 30 cuttings.

The preceding examples apply to plants that are normally considered difficult to root. Let us now look at an example from a study done with a plant considered relatively easy to root. Semi-hardwood terminal cuttings of convex leaf Japanese holly were also taken on 15 August, trimmed to 15 cm (6 in.), and treated as listed in Table 3. Cuttings were then subjected to the same conditions as southern wax myrtle and Leyland cypress. Data were also recorded 77 days later. Cuttings treated with 0.5% or 0.75% IBA liquid quick dip and Hormodin 3 rooted 80.0, 93.5, and 90.0%, respectively, compared to untreated cuttings, which rooted 40.0%. This is an example of where both the talc and liquid formulations of IBA were

equally effective in terms of percent rooting. However, if we look at the number of roots per cutting, the 0.75% IBA liquid quick-dip produced 30.4 roots/cutting compared to 16.2 for Hormodin 3. Recall that Hormodin 3 contains 0.8% IBA in talc form.

Table 3. Response of *Ilex crenata* 'Convexa' to selected rooting compounds.[z]

Treatment	Percent Rooting[y]	Mean number of roots/cutting	Mean root length (mm)
Untreated	40.0 b	2.7 c	18.1 a
0.5% IBA liquid quick-dip	80.0 a	16.9 b	18.0 a
0.75% IBA liquid quick-dip	93.5 a	30.4 a	20.2 a
Hormodin 3 (0.8% IBA in talc)	90.0 a	16.2 b	14.6 a

[z]Means within a column folowed by the same letter are not significantly different at the 5% level — Duncans New Multiple Range Test.
[y]Each value based on 30 cuttings.

The foregoing provides some examples which substantiate the fact that auxin concentration as well as method of application can dramatically affect rooting of some species. This should be of concern to commercial propagators and nurserymen who wish to maximize both production and production efficiency. In our experience, liquid formulations of IBA are easier to apply than talc formulations since cuttings can be treated in bundles at one time rather than individually.

The mention of trade names does not imply endorsement by the North Carolina Agricultural Research Service of products named or criticism of similar products not mentioned.

PROPAGATION: FOG NOT MIST

TIMOTHY F. PRESS
Mee Industries, Inc.
San Gabriel, California
(See Western Region, page 100)

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PROPAGATION AND LINER PRODUCTION AT JAMES NURSERY

MALCOLM JAMES

James Nursery
P.O. Box 288
Byron, Georgia 31008

James Nursery was begun in 1967 on a very small scale — approximately 16,000 liners per year. We now produce about 1 million liners a year, consisting of 22 cultivars of ornamentals. Of this number, 50% are *Photinia* × 'Fraseri'.

We operate with three full-time workers — Malcolm and Edward James, and Malcolm's son, Jonathan. Other family members work when needed. We hire six high school students for approximately 7 weeks in May and June, when time is of the utmost importance in order to have all our cuttings in by July 1, after which the rooting response is not as good.

We have been asked what is the most important part of liner production. The correct answer would be, "All of them." You must begin with a good stock plant, for you cannot produce a good liner from weak or diseased stock. On the other hand, if you have the best cuttings available but fail to furnish a good rooting medium or watering program, you will still have a failure.

Our physical layout consists of two shade-houses 196 ft. by 108 ft. by 8 ft. Within each section are 16 rows of PVC pipe with Flora-Mist nozzles on each row. We control each house by a 24-hr. clock, and each section within the house is controlled by a 5-min clock that operates a solenoid valve. Each section holds 32,000 liners. Each row of 16 nozzles is controlled by a hand-operated valve to be used in case of clogging or other problems in the line.

The houses are constructed by using 4 × 4's placed on 12-ft centers. Between each row of posts we build 2 beds 58 in. wide. This leaves 24 in. for a work aisle. We place 2 rows of PVC pipe 28 in. apart with a 20 in. riser every 36 in. Our houses are covered with a 47% shade cloth. Originally we used lath to cover but find it creates drip problems when it rains. The houses are constructed so that we can use pecan equipment for spraying. We get very thorough coverage by moving through the house only one time.

We grow all our own stock plants in order to insure that we start out with a good, strong, disease-free cutting. Each year we cut our stock plants back to within 2 in. of the previous year's cut. This helps maintain the production of

young, vigorous growth for propagation. We take our cuttings about 5 to 6 in. long and dip them in a fungicide. We then strip the lower leaves and dip the stems in a 0.1% IBA solution for photinia and 0.3% for junipers. The only wounding is from stripping the leaves. They are then ready for sticking directly into 3-in. pots. We use S-300 Lerio containers. Cuttings are stuck within 30 min. of the time they were cut.

We place all our pots directly on the ground. Each bed will hold 21 pots across. Since the workers cannot reach the entire distance across the bed, we place pots in the back half, fill with mix, which is misted every 5 min. overnight to secure a well-moistened medium. We then top with more mix, "firm" it so that the cuttings will stand without being blown over, and stick the cuttings in this back half. The whole procedure is repeated on the front half.

Our mix for photinia is 1 part peat to 1 part perlite with approximately 9 ft^3 coarse sand for each 2 yds^3 of mix. We use coarse sand to give us better drainage. We add 15 lbs of limestone and 10 lbs Pro-Start 16-6-6 fertilizer per yd^3.

We use a mix of 3 parts finely ground bark, 1 part sand with 15 lbs limestone, and 10 lbs Pro-Start 16-6-6 fertilizer per yd^3 for all our other cuttings.

Our mist is started before the cuttings are stuck to assure that the cuttings never dry out. The misting cycle usually begins at 9 am and stops at 7 pm. This will vary depending upon the weather. Even though we have an automatic system, it is important that someone check 2 or 3 times every day to insure that it is operating properly.

We stick junipers in January or February. Our dwarf yaupon (*Ilex vomitoria* 'Schillings Dwarf') are stuck in February using bottom heat supplied by a 30-gal water heater. The water is circulated through ½-inch PVC pipe by a small pump (1/25 hp). This house is 12 ft. wide by 48 ft. long with 4 rows of pipe, 16 nozzles per row.

After our cuttings have rooted, we apply fertilizer (Sta-Green Super Nursery 20-5-10) at 1 lb/100 ft^2. We follow a spray program of applying a fungicide and insecticide combination every 3 weeks. We keep a close tab on all plants, and if we note a disease or insect problem developing, we spray the entire nursery.

We get from 95 to 100% "take" on all our liners. Our spray program includes Benlate, Du-ter, the herbicides Roundup and Paraquat, and other pesticides that are recommended for specific problems.*

After our plants have grown to a desirable size, they are held in pine-shaded areas until sold. They are then shipped, packed in wax-coated boxes, by customer truck.

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*Benlate - benomyl, DuPont
Du-ter - triphenyltin hydroxide; Duphar, Thompson-Hayward
Roundup - glyphosate, Monsanto
Paraquat - paraquat, Chevron

PROPAGATION AND CULTURE OF *PIERIS JAPONICA* CULTIVARS

BRIAN A. NELSON

Nelson Nursery
727 Carpenter Avenue
Mooresville, North Carolina 28115

Pieris japonica is a broad-leaved evergreen shrub of neat, compact habit, valued in the landscape. It is native to eastern Asia and was introduced into culture around 1870. Most *Pieris japonica* cultivars are of slow to moderate growth rate, seldom exceeding 6 ft. in height and width after many years of growth. *Pieris japonica* offers attractive dark green leaves with a prolific display of flowers in early spring that range in color from white, pink, pink and white bicolor, to red. The young foliage is highly colored with some selections having a most brilliant red new growth. Leaves are alternate, from 1 to 3½ in., with a slightly toothed margin. Flower buds are formed in late summer and are held in terminal, drooping clusters 5 inches long. When open, the flowers resemble those of lily-of-the-valley.

Propagation. *Pieris japonica* can be successfully propagated from seed and by cuttings. Seed can be collected as soon as it is ripe. The seed is sown in flats of peat from late summer through early spring.

We propagate *Pieris japonica* from softwood and greenwood cuttings. The cuttings are collected in the early morning hours during July and August from plants growing in production blocks. The terminal growth of new wood is preferred. Cuttings are trimmed to 4 to 5 in. in length. Lower leaves are easily stripped by hand, leaving only the uppermost 3 to 6 leaves. We prefer to use a single wound but are not at all convinced that wounding is a necessity.

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In years past we have used IBA in talc at the rates of 5,000 to 8,000 ppm. Presently we are using IBA in a quick-dip solution. The IBA crystals are dissolved in isopropyl alcohol to yield 3000 ppm IBA. The basal end of the cutting is dipped into the solution. Combinations of IBA and NAA are being tested and the resulting trials evaluated.

The cuttings are placed at 2 per container into 2½ in. wide by 5 in. deep open-bottomed tree pots. The tree pots are filled into a basketweave-bottomed flat. The rooting medium consists of equal portions, by volume, of peat moss, pine bark, and perlite, to which slow-release fertilizer and trace elements have been added. The cuttings are watered and then placed in rooting beds under a white poly tent. The cuttings are checked several times throughout the day and mist is applied as necessary. Rooting is slow, often taking 6 weeks or more. While under the mist cuttings are sprayed with Manzate D and Benlate. As the cuttings are rooted, the mist is gradually reduced until it is cut off altogether. The poly tent is then covered with a sandwich-like layer of white poly, microfoam, and clear poly. No supplemental heat is provided during the winter. In the spring the young plants break into new growth very uniformly with plants in harmony with the production cycle.

The use of proper timing, hormone treatment, and aftercare give an actual yield of about 95% rooting. The use of two cuttings per container gives an effective yield of very high 90% rooting. By using the open-bottomed tree pots, we have promoted an elongated root system that is well defined, well branched, and transplants easily with very little shock.

Culture. The successful production of *Pieris japonica* requires many of the same conditions as *Rhododendron* production. In our geographical area it requires partial shade with high filtered shade preferred. The amount of water held in the root zone should be closely monitored. Too much available water invites problems. We finish the plants in a gravel-covered production area. Success in the landscape requires a soil that provides excellent drainage. Most soils should be amended with peat moss, pine bark, and sand.

***Pieris* cultivars of merit:**

1. *Pieris formosa* var. *forrestii* (Chinese pieris). Introduced from China by George Forrest around 1910; used widely in Europe where it is hardy; young foliage is brilliant scarlet when it emerges.
2. *Pieris* 'Forrest Flame'. Hybrid of *Pieris formosa* var. *forresstii* 'Wakehurst' × *Pieris japonica*; chance seedling in Sunningdale Nurseries about 1946; bright red new growth with white flowers; larger than *Pieris japonica*; hardy.

3. *Pieris japonica* 'Daisen'. Selection by K. Wada from Mount Daisenin in Japan; flowers deep pink in bud, fading upon opening, leaves are wider and smoother than most; deserves more use.
4. *Pieris japonica* 'Valley Rose'. Introduced by Dr. Robert Ticknor of North Willamette Valley Experiment Station in Oregon; very compact habit, deep pink buds fade when open; delivers what *Pieris japonica* 'Dorothy Wyckoff' promises.
5. *Pieris japonica* 'Variegata'. Slow growing; leaves green edged with cream; new growth green, pink, and cream; very attractive.
6. *Pieris japonica* 'Pygmaea'. A novelty; in growth and form similar to *Rosmarinus officinalis*.
7. *Pieris japonica* 'Christmas Cheer' and *Pieris japonica* 'Valley Valentine', two of the more colorful flowering cultivars.
8. *Pieris japonica* 'Mountain Fire'. Introduced by Dr. Robert Ticknor; superb brilliant red new growth emerges several times a year; excellent.

PROPAGATION OF SOME RARE TROPICAL PLANTS

SHIVU I. PATEL
Everglades Sod and Landscaping, Inc.
19100 Krome Avenue
Miami, Florida 33187

The purpose, objectives and goals of this article are to *provide an overview of the propagation, multiplication, and* production techniques of some rare and tropical plants grown and utilized in Florida rural and urban landscaping. From several thousand rare, exotic and tropical plants, only a few of the most that are highly utilized for residential as well as for commercial landscaping were selected for discussion.

The opinion, comments, remarks, suggestions or criticisms offered or most encountered problems within this article should be useful to plant propagators and nurserymen throughout southeastern United States. It may bring or provide to the average nurserymen information and practical propagation knowledge of plants used in landscaping in our subtropical parts and provide a guideline in the choice of plants that do well in the warmer regions of the state of Florida.

(1). *Acacia auriculiformis*, Leguminosae. Earleaf acacia is native to Australia. Best adapted to cool, sub-tropical, or warm temperate climates, this medium-sized tree is semi-deciduous

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(1). *Acacia auriculiformis*, Leguminosae. Earleaf acacia is native to Australia. Best adapted to cool, sub-tropical, or warm temperate climates, this medium-sized tree is semi-deciduous

and fast-growing. It does best in slightly dry soil. It is available in many nurseries.

Propagation: This acacia is propagated by seed, germinated in a lathhouse or 30 to 40% shade. A sterile, moderately heavy, sand and peat, or peat-containing medium is preferred. The seed coat should be softened by soaking in warm (75°F) water for 1 to 2 days. Sometimes to hasten germination the seed is scarified or a cut is made through the thick, hard coat. Keep the seed bed moist.

(2). *Arecastrum romanzoffianum* (Cocos plumosa) Palmeae. Queen palm is native to Brazil; it has a tall single trunk, reaching to 50 ft. in height; tree width is from 12 to 15 feet. This specimen tree creates a tropical effect and is used in landscapes or street plantings in central and south Florida. It thrives best in full sun. Three-feet long yellowish spathes appear in summer. The fruits are no more than 1 in. long.

Propagation: The queen palm is propagated by seeds. The seeds should be kept cool until planted. The fresh seeds grow easily in sun or partial shade in well-drained sandy soil. The growth rate is moderate to fast. Recommended germination procedures are similar to those for pigmy date palm. Seeds should be soaked in slightly warm water for 2 or 3 days. A satisfactory medium consists of Florida peat, 40% pinebark or cypress sawdust, and 20% sand. Avoid addition of any kind of fertilizer during germination.

(3). *Bucida buceras*, Combretaceae. Black olive. This semi-deciduous tree reaches 30 ft. or more in height. It is useful planted in groups or parkways or sometimes as a single specimen as it is salt tolerant and wind-resistant, good for south Florida areas. It is usually grown in full sun to give dense evergreen foliage. It is commonly available in south Florida landscape nurseries.

Propagation: Black olive is generally propagated by seeds. It produces small, greenish yellow flowers in the spring, which are borne in spikes. Fruits are curved, oval, about ⅓ in. long. Growth rate is very slow, even in fertile sandy-loam soil. Sometimes propagated by marcottage practices. Terminal softwood cuttings taken during spring when a fresh flush of growth is evident can be propagated under mist using 50% perlite and 50% peat; 30 to 40% shade conditions, where air temperature does not exceed 90°F, are important. In fact, rooting is better at 65 to 75°F. Excess water consistently results in failure to root. The use of Hormodin #3 is helpful.

(4). *Calphyllum inophyllum*, Guttiferae. Beauty leaf, kamani, or alexandrian laurel is native to the shores of the

Indian and western Pacific oceans. It has very fragrant white flowers and is tropical in nature.

Propagation: The green fruits are in pendulous clusters. They have thin leathery skin covers and hard-shelled coats. The seed coat may be softened by soaking in 75°F water, about 3 to 4 times their volume, for 10 to 12 hours. Before planting the seeds in seed bed or flats, a 10-min. soak in fungicide such as Banrot 40% WP (¾ lb/100 gal. of water) has proven helpful. A moderately heavy but well-drained, moist, well-aerated propagation medium gives good germination. A 30 to 40% shade level, 75 to 85°F air temperature, high humidity, are required. Cover the seed but not too deeply.

(5). *Chrysobalanus icaco*, Chrysobalanaceae. Coco plum in south Florida natural conditions is a small, native, evergreen tree reaching 10 to 15 ft. The dark green, glossy-leaved coco plum grows moderately in a wide variety of soils. It has high salt tolerance and withstands flood conditions. It does not tolerate drought. Coco plum fruit and nuts are edible. It is recommended for south Florida landscape. However, it is not readily available.

Propagation: It is propagated by seeds and softwood cuttings. Long cuttings are made from current season's growth, treated with Hormodin #1 and placed in a propagating frame, using 50% perlite and 50% peat medium; 30 to 40% shade is preferred. Semi-hardwood cuttings may be taken during fall and winter and rooted under mist house conditions. They root in 6 to 8 weeks with high humidity, 60 to 70°F air temperature, and a moist but well-aerated medium. Seeds should be planted in spring in sterile well-drained medium. Scales and some caterpillars may be troublesome. Green tip and red tip coco plums are widely grown in several nurseries.

(6). *Clusia rosea*, Guttiferae. Autograph tree, pitch apple, or pat pork tree, this south Florida native apple-like evergreen tree reaches 25 to 30 ft. in height. It has a moderate growth rate and bears large pink and white flowers. It is preferred mostly because it requires little maintenance and has high salt tolerance. The growth is medium, and it has a value as a flowering tree. Scale can be a problem.

Propagation: It produces 1½ in. apple-like fruits; seed should be planted as soon as ripe. Remove fleshy coat, or soak in water for 1 to 2 days before planting. Use sterilized propagation medium in flats or beds. Peat:sand:soil, 1:1:1 by volume is acceptable and proven satisfactory. Keep soil moist, provide 30% shade, and keep daytime air temperature between 85° and 95°F. The seed should germinate within 30 days. Seedlings

may be transplanted as soon as leaves are well-developed to keep a straight stem habit.

(7). *Coccoloba diversifolia*, Polygonaceae. Pigeon plum is a native Florida tree and is semi-deciduous, slow-growing, reaching heights of 40 ft. It has high salt tolerance and is commonly found on seaside locations.

Propagation: The small purple fruits contain seeds smaller than those of seagrape. They are easy to grow either on a ground bed or in deep flats containing slightly heavy, but well drained, sandy soil.

(8). *Coccoloba uvifera*, Polygonaceae. Seagrape is native to Florida and is a semi-deciduous, slow grower reaching 25 ft. with a spreading growth habit. It has high salt tolerance, and is commonly found on beaches. Most south Florida nurseries grow this plant.

Propagation: The small, grape-like ½ to ¾ in. fruits should be collected from August to November. Seedlings are grown either in a seed bed or in deep flats containing moderately heavy, but well-drained soil. Some growers have success propagating by cuttings and by air-layering. The seed coat of mature seeds is easy to peel off; no other special treatment is required. Seeds should be planted before drying out. Seeds must be covered to a depth equal to the size of the seeds. Ants can be a problem during germination. Apparently seeds contain a sugar source. Other problems include scales, rust, and caterpillars. Sometimes twig pith borers and leaf spot problems also appear.

(9.) *Cocculus laurifolius*, Menispermaceae. Snail seed is native to the Himalayan region and is found and grown in Florida. It forms a small tree or shrub with evergreen foliage and a weeping habit of growth. It does not tolerate salt or too much wind.

Propagation: The standard method of leaf-bud cuttings under intermittent mist in the spring is preferred. Cuttings from young shoots can be rooted in the greenhouse or other propagating structure in 40% perlite, 40% peat, and 20% sand medium. The cuttings should be taken in the spring from mature shoots and should consist of a leaf blade plus a short piece of the stem with the axillary bud. Scales can be troublesome.

(10). *Conocarpus erectus*, Combretaceae. Button mangrove. Buttonwood is commonly known as green buttonwood and C. *erectus* var. *sericeus* is silver buttonwood. It is native to tropical America and West Africa. These button mangroves are attractive, prostrate shrubs or small trees. The silver buttonwood has oval-shaped, glossy leather leaves with a silvery

cast. Both thrive best in a humid tropical climate. They are widely used for ocean-front landscaping in south Florida as they are tolerant of lime soils. Sooty mold is a common problem.

Propagation: The plants have greenish flowers and purplish fruit. Fruits are observed in clusters up to ½ in. in diameter. Propagation is by softwood or semi-hardwood cuttings. Keep the moisture level low. Leaf drop is a common reaction to an improper propagation medium or high temperature.

(11). *Dalbergia sissoo*, Leguminosae. Indian rosewood is a deciduous tree from India and grows to 70 to 80 ft. It thrives best in central and south Florida. This shade tree has semi-deciduous leaves, fragrant, yellowish-white flowers, and 2 to 3 inch papery pods containing 1 to 3 seeds. It has low salt tolerance. Sometimes caterpillars are troublesome.

Propagation: Seeds germinate easily in a light-weight medium, with only minimum watering during germination. Seedlings grow rapidly and do best in full sun after germination. Indian rosewood may also be air-layered. It can be transplanted bare-rooted.

(12). *Manilkara zapota*, (Achras zapota). Sapotaceae. Sapodilla is native to south Mexico and central America. The fruiting season is from spring to summer, February to November. The fruits are edible fresh or frozen. Its medicinal and economic values are as a source of latex, a source of chicle, and as an ornamental. Sometimes fruits are used for sherbets and in ice creams and for making sapodilla halwa, a kind of Indian sweet. It is a medium-sized, excellent slow-growing ornamental evergreen tree. It is wind and drought tolerant but moderately salt and cold tolerant and poorly flood tolerant. It is only occasionally found in nurseries. Recommended for planting in south Florida. Grows very well in Florida.

Propagation: The large, brown, sweet-pulped fruits have several flat black seeds. Seed propagation is a common method; grafting is rarely used. The hard-coated seeds must be soaked overnight in warm water (70-75°F).

(13). *Phoenix roebelenii*, Palmae. Pigmy date palm or Roebelin palm is native to China; dwarf palm has a trunk 3 to 4 in. in diameter. Leaves are pinnate, 4 to 6-ft. long. It is used as a potted specimen, in a patio planter box, or for a tropical effect, as its crown is like an umbrella. It grows slowly, needing a slightly acid well-drained fertile soil. It thrives best in full sun or partial shade in Florida. It tolerates light frost but not salt. The pigmy date palms are dioecious, having 10- to 12-inch greenish-yellow flowers in May and June. The ½ inch

fruits are oblong, purplish black. Florida red scale and fungus are common problems.

Propagation: It is mainly propagated by seed. Pigmy date palm seed, like Aerca palm seed, germinates easily in about 1 to 3 months in sterilized media of peat:sand 1:1 v:v or peat: vermiculite:sand 1:1:1 v:v:v. Seed treatment with ferbam or ziram is suggested. It is said that fresh-ripened, mature seeds are more likely to germinate. The recently-harvested seeds could be stored for 2 to 3 weeks, but the fleshy coat must be removed, and the seeds should be dried out in a shady area before storage. The scarification process or cutting through the thick or hard seed coat helps to hasten germination. Always keep the flats or seed bed moist and maintain high temperature until germination. For some palms the higher the soil temperature, the higher the rate of germination. The pigmy date palm seeds of common kinds germinate readily if sown in flats of soil and placed in a bottom heat of 80°F.

(14). *Roystonea elata*, Palmae. Florida royal palm is a tropical tree from South Florida thriving best in nearly frostless locations in full sun or partial shade with rich fertile moist sandy loam soil. It is salt tolerant and is sensitive to cold, but has a nice clean, upright habit of growth. It reaches 30 to 50 ft. in overall height. It is readily available. Scales are a common problem.

Propagation: Propagation is by seed. Fruits are black or bluish, berry-like drupes, ½ in. long. Procedures described for propagation of pigmy date palm should be followed to germinate royal palm seeds.

(15). *Scaevola frutescens*, Goodeniaceae. Beach naupaka, scaevola. Native areas known for this plant are the coasts of the Indian and Pacific Oceans. It is grown widely in the warmer parts of Florida. This quick-growing plant bears white, fleshy berries from September to November. It is mainly used for hedges and soil erosion control for coastal areas and for landscaping sandy locations. It is a fast growing evergreen and needs frequent trimming. However, it has good wind resistance capacities. Problems include poor salt tolerance, moderate cold tolerance, and sensitivity to drought. Mites can be troublesome. The plant is a preferred landscape item but is usually not available in the nurseries.

Propagation: Scaevola is propagated by seeds or from cuttings. The seed coat may be softened by soaking overnight in tap water. Softwood cuttings in summer may be rooted under lathhouse or 30 to 50% shade conditions. Hormodin 1 is helpful. A light weight propagation medium is important as it is

very subject to root rot. Softwood cuttings usually root in 6 to 8 weeks.

(16). *Swietenia mahagoni*, Meliacae. Mahogany is known to be native to Florida and the Keys and is cultured in warmer areas of South Florida. It is tall, semi-deciduous, best adapted as a framing shade tree. It is slow-growing but has a high salt tolerance. The Cuban maybeetle, caterpillars, web worm, and scales can be problems. Mahogany is readily available in Florida nurseries.

Propagation: Seeds are borne in brown-gray pods, 4 to 6 in. long, hanging from cords. The seeds mature in winter and germinate easily without soaking. A light weight propagation medium and partial shade are best and should be covered lightly. The major problems are caterpillars and damping-off after the emergence of the seeds.

(17). *Tabebuia argentea*, Bignoniaceae. Gold tree or silver trumpet tree is native to Paraguay. It grows moderately, reaching 20 to 25 ft. in height and 15 to 20 ft. in width in Florida climate. The light-colored bark is cork-like; golden yellow flowers in April are spectacular.

Propagation: Seeds germinate easily and cuttings or air layering can be used. It grows rapidly in a light-weight 50% perlite, 50% peat medium. Thoroughly soak the medium and seeds with captan, Ferbam, or other recommended fungicide for damping-off control.

(18). *Tamarindus indica*, Leguminosae. Tamarind is a large tree native to India. The brown-pulped, date-like pods develop from April to June. They are used for drink, preserves, and chutney. This evergreen tree has a moderate growth rate, but has good wind, salt, and drought tolerance. Cold and flood tolerance are poor. It is recommended for planting in south Florida.

Propagation: Tamarind is mainly propagated by seeds. Air-layering and grafting are also practiced.

(19). *Zamia floridana*, (Coontie) Cycadaceae. This dwarf, herbaceous, palm-like plant, native to central and south Florida, is evergreen and preferred as either a foundation planting or a potted specimen. It is hardy in Florida and is salt tolerant. Coontie has no fragrance but tolerates sandy soils and grows either in sunny or shady locations. However, it is difficult to transplant. It is related to Queen Sago.

Propagation: Cones, containing orange seeds, mature during fall and winter. The seeds are used for propagation; however, germination is very slow, and chances for losing seeds are high. Well-drained porous soil is important. For better

germination remove the seed coats by mechanical means, or soak seeds in concentrated H_2SO_4 for one hour then wash thoroughly with tap water. This treatment can give 95 to 98% germination. It is also reported that soaking in 1000 ppm GA hastens germination. Occasionally plants are gathered from the woods, the tap roots cut back and replanted. The root pieces are then used for propagation. The roots should be dipped in Daconil to avoid decay. Florida red scales are major pests. It is hard to transplant coontie plants.

ACKNOWLEDGEMENTS

Special mention needs to be made of certain individuals, namely: Mr. Larry Lavargna, Vice-President, Everglades Sod and Landscaping, Inc. for his approval and assistance; Mrs. Rosemary Berenguer, Executive Secretary; and Miss Ricci Rankine, Secretary, for their typing help, proof reading, and cooperating.

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3. Neel, P. L. 1979. Macropagation of tropical plants as practiced in Florida. *Proc. Inter. Plant Prop. Soc.* 29:468-480.
4. Perry. P. and J. W. Boodley. 1981. Foliage plants from seeds. *Nurserymen's Digest.* 10:101-104.

PROPAGATION AT GREENBRIAR NURSERIES

BILL REESE

Greenbriar Nurseries, Inc.
2025 Northeast 70th Street
Ocala, Florida 32670

Greenbriar Nurseries was started in 1974 and produces hardy, woody ornamentals on 21 acres in north central Florida. We produce all of our own liners and the procedures used in propagation as well as our costs and method of productivity are described as follows.

We get most of our cuttings from our landscape scheme as well as from our inventory of container material.

The trays we use are approximately 12 in. × 18 in. and we use a 40-cell insert made by Growing Systems. We get approximately 5-yr. use from the tray and 3-yr use from the insert.

Our soil is mixed for us locally and consists of 4 parts native peat, 3 parts composted pine bark, 3 parts Soilite (ex-

germination remove the seed coats by mechanical means, or soak seeds in concentrated H_2SO_4 for one hour then wash thoroughly with tap water. This treatment can give 95 to 98% germination. It is also reported that soaking in 1000 ppm GA hastens germination. Occasionally plants are gathered from the woods, the tap roots cut back and replanted. The root pieces are then used for propagation. The roots should be dipped in Daconil to avoid decay. Florida red scales are major pests. It is hard to transplant coontie plants.

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Our soil is mixed for us locally and consists of 4 parts native peat, 3 parts composted pine bark, 3 parts Soilite (ex-

panded rock ⅛ in. max.) with 3 lbs dolomite per yd^3 and ¾ lb Micromax/yd^3.

We built a fumigation chamber approximately 8 × 16 × 4 ft and use methyl bromide at the rate of 4 1-lb cans per chamber per treatment. We apply Osmocote (18-6-12) 9-month formula as a top dressing prior to sticking cuttings.

The structures used at Greenbriar Nurseries include a shade house using 30% shade cloth, a poly-covered house, and a full sun area.

One of our more popular plants is "Texas sage", *Leucophyllum frutescens (L. texanum)*. We take cuttings from plants growing in #3 containers. We take about 4 to 5-inch cuttings on moderately woody stock, which represents current years growth. The best time of year for taking sage cuttings is from June 1 to July 15. Our propagating crew works on cuttings in a shady location. We use the rooting compound, Dip n' Grow, at 0.25% strength, applied as a quick-dip. Dip n' Grow contains the rooting hormones, IBA and NAA. We move rooted liners to a lightly shaded area to harden off for a period of at least 45 days to 6 months until potting time. We apply a granular herbicide, OH-2 by Scotts,* with an Echo backpack unit.

Now, for the rest of the story. At Greenbriar Nurseries we believe in 3 P's:

PEOPLE-PRODUCTIVITY-PROFIT

We start with our people. We work closely with our county school system and use vocational agricultural students. Of our 12 full-time employees, 8 worked for us part-time as vo-ag students in high school. We also employ vocational students from our local junior college. Each year we use a University of Florida horticulture student from the University work experience program. Now, how do we take 12 full-time and 12 part-time people and make them highly productive?

Our productivity is measured daily on an individual basis. Each propagator has his own color tag, which is put in each tray he prepares. Daily cutting totals are kept and an average cutting per man-hour is figured. We set an individual goal of 300 units per man-hour. All totals are posted daily and recognition is given to all who exceed the 300 p.m.h. goal. Group rates are posted and recognition is given at our Friday employee lunch meeting. Weekly and monthly production goals are set and posted as well.

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* Ornamental Herbicide 2 (2% oxyfluorfen, 1% pendimethali), O. M. Scott

We instill pride in our product by giving our propagators a great portion of credit for the quality of the plant material we are selling. Also, all of our full-time people, including our truck drivers, salesmen, and office help, will rotate into our propagating crew to keep up their identification with our product and to maintain a high proficiency of production. Propagation at Greenbriar Nurseries is not looked on as menial work but more as an opportunity to better the product and to insure the ability to make a profit. We have told our full-time employees that we must make a profit, and we want them to share in it also. We budget 2% of our gross sales for a profit-sharing pool. If we make profit — and so far we have — we distribute this, based on productivity of the various groups.

Now for the last P — Profit. Our propagation program is a big contributor to our overall profit. We keep our employees informed of this fact. Our costs of production for this year are as follows: For 500,000 cuttings, our labor costs were $8,700, which includes taking of cuttings, preparing and sticking, filling trays with soil, and moving them to fumigation areas and to and from the mist area. It also includes maintenance labor for fertilization and herbicide application as well as supervision time. Our material costs were $6,220 which includes soil, trays and inserts, chemicals, and fertilizers. Total direct costs were $14,920 for 400,000 liners for a direct cost of $0.037 per unit. Total indirect costs to propagation were approximately $17,500 or a cost of $0.043 per unit. This produces a total cost of $0.08 per unit for each liner. We build a 10% loss factor into our final cost and the total cost per unit becomes $0.09.

We feel people are the answer to productivity and profitability problems. We have had excellent results from sharing profits with our employees and making sure they feel they are an important part of the team.

ROOT-ZONE HEATING INNOVATIONS IN FLORIDA[1]

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Abstract. Trends in bottom heating in Central Florida are reviewed with emphasis on heat placement and techniques of heat trapping. A study involving three different heating chambers for potted plants is described. Findings indicate that a temperature increase of 4° to 5°F can be achieved within medium in 6-inch pots if chambers are utilized, compared to medium temperature of free standing container-grown plants with heating pipes between them.

REVIEW OF LITERATURE

Most Central Florida greenhouses are heated with forced air heaters that distribute heat rapidly throughout the structure. This is not the most efficient use of heat since many crops root and grow best when root temperatures are between 70° to 80°F, which is above the air temperatures maintained by normal space heating. Mechanisms for placing heat where it is most beneficial to horticultural plants are desirable.

Many warm-water bottom heating systems used in northern United States and Europe for medium and large potted plants involve heating a greenhouse bench top or floor on which the containers rest during crop production. The heating pipes are either placed under the bench, embedded in the floor, or lie on top of the bench or floor surface.

The system being employed by most Central Florida growers equipped with bottom heat is a closed warm-water system composed of a heating unit, a network of distribution pipes and a circulating pump controlled by a thermocouple placed in the root zone and linked to a thermostat (3,5). Water temperatures in pipes range from 100° to 115°F in most systems, which permits heat placement close to plants without root damage. Polyvinylchloride (PVC) and polybutylene pipe are presently

[1] Florida Agr. Exp. Sta. Journal Series No. 5402.

the most popular types of pipe used for warm water distribution. Pipe spacing is important under these conditions because most media used for propagation and growing horticultural plants are rather good insulators, even when moist. Because of the insulating quality of the media, appropriate amounts of heat should be placed as close to the roots as possible (5,7). The temperature gradient measured in a commercial propagation bench filled with peat to a depth of 4 in. is shown in Figure 1(6). One half-inch diameter schedule 160 PVC water pipes were placed on the bench bottom on 9-in. centers. The soil next to the pipe was 100°F while the soil temperature between the pipes, at pipe level, was 71° to 72°F.

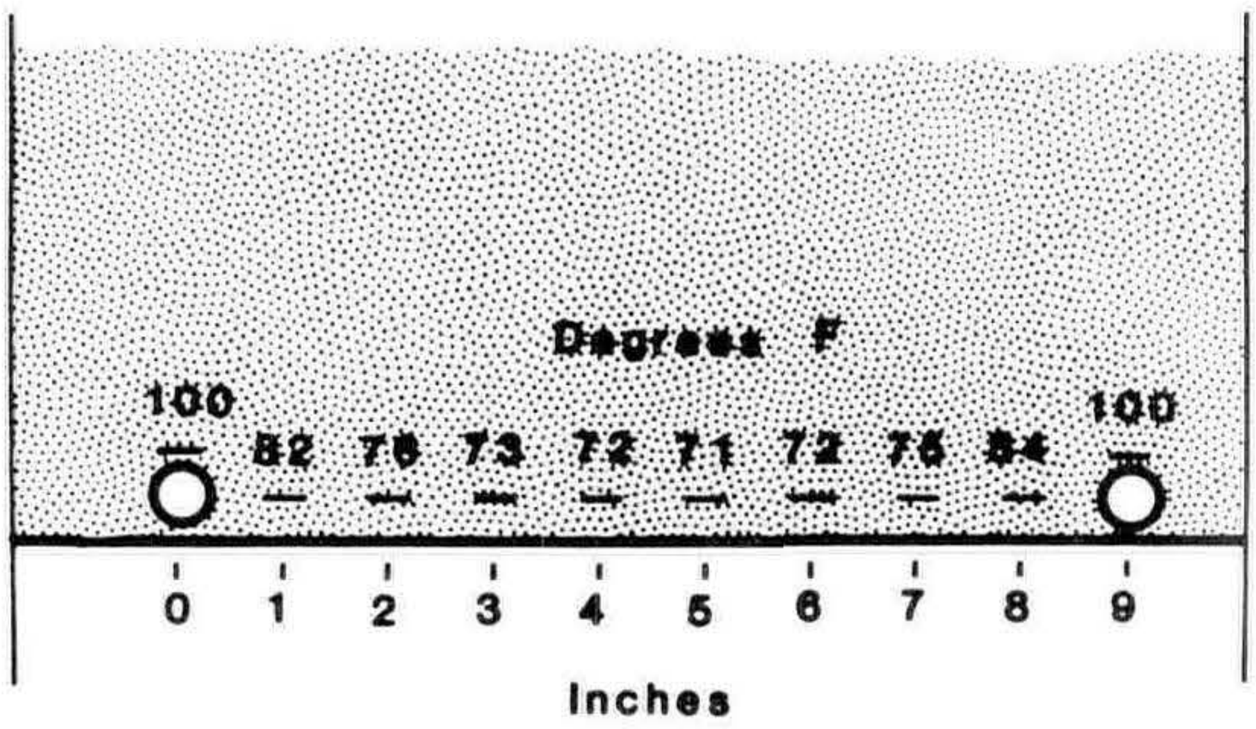

Figure 1. Temperature gradient at pipe level between ½-inch PVC warm water pipes in a propagation bench filled with 4 inches of moist peat moss.

Since most root-zone heating systems in Florida are installed in benches or beds for growing free-standing potted plants, greater efficiency of warming soil in these pots, particularly those spaced on wide centers, can be achieved through chambering techniques to reduce the rate of heat transfer to upper levels of greenhouse (7).

Initial studies in 1980 involved nightly measurements of temperature gradients in 6 in. standard plastic pots filled with Metro-Mix 500 in a greenhouse (7). Figure 2 illustrates the pattern of temperatures recorded in three treatments: 1) non-bottom heated, 2) bottom heated, and 3) bottom heated with chamber around the pot. Bottom heating without the chamber simulated bottom heating as practiced by many growers in northern United States and Europe. There was benefit in bottom heating this way (Treatment 2) because the mean soil temperature was 10°F above non-bottom heated soil. Additional benefit was realized when a chamber was used in conjunction with bottom heating (Treatment 3), with an additional 8°F rise in soil temperature with no additional energy expenditure.

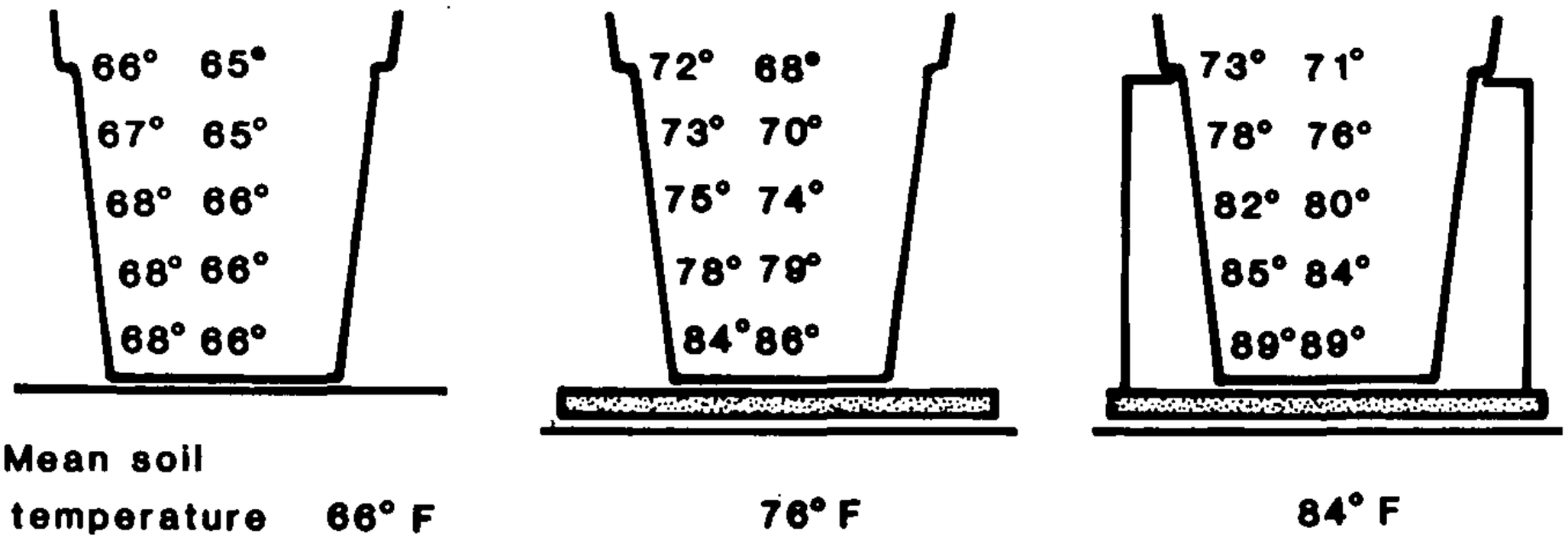

Figure 2. Soil temperature gradients measured in 6-inch pots exposed to no bottom heat, bottom heat, and bottom heat plus a chamber.

MATERIALS AND METHODS

The following work was conducted to determine the effects of chambering 6-in. potted *Aglaonema* 'Silver Queen', which were grown on raised benches equipped with a warm water bottom-heating system. The experiment was conducted in a fiberglass-covered greenhouse lined with 4-mil polyethylene film at Melco Nurseries, Inc., Apopka, during autumn-spring, 1981-1982. Air temperature within the greenhouse was maintained at a minimum of 65°F through use of gas-fired, forced-air unit heaters.

The warm water system used for bottom heat consisted of a hydronic boiler, hot water circulating pump, a network of plastic pipe, and a thermostat with thermocouple to control the circulating pump based on temperature in the pots. A 266,000 BTU liquid propane-fired Raypak hydronic boiler supplied warm water to 17 benches, 5 ft × 64 ft, a total of 5440 ft^2 of actual surface for growing. There were 17 other benches in the same greenhouse range that were not bottom heated. Water was distributed to the benches in PVC pipe ranging from 1- to 2-in. diameter, with 1-in. headers at ends of each bench. Water was transported through 7 16-mm diameter polybutylene pipes positioned on 15-in. spacing between each row of pots running the bench length. Black polypropylene ring clamps secured the pipe to the header adapters.

A ½-hp Craine-Deming pump, model 4353, was used to circulate water through the system upon signal from a Penn

thermostat plus thermocouple with an 8-ft. lead used to monitor soil temperature in one pot. The thermostat turned the circulator on as the medium reached 70°F and off at 73°F. The boiler operated only when water was circulated through the system and modulated its fuel consumption downward to 25% of full capacity, depending upon the energy required to reheat the return water.

The warm-water system was installed on existing wire-fabric-covered benches, which were modified slightly through placement of clear, corrugated, 4-oz. fiberglass over the wire fabric to increase bench top rigidity and reduce heat loss through the bottom.

The experiment consisted of 5 treatments: 1) no bottom heat; 2) bottom heat with water pipes exposed without a chamber; 3) bottom heat plus a molded plastic chamber; 4) bottom heat plus a chamber constructed of ¾-in. thick wooden sideboards mounted 6 in. high with 6-mil black polyethylene straps attached across the top, running both the width and length of the chamber to form square openings for pot insertion; and 5) bottom heat and wooden sideboard chamber plus a series of square $\frac{3}{32}$-in. thick Microfoam squares, approximately 13 × 13 in., which had a 4-in. diameter hole in the center. The squares rested on the upper pot rim and overlapped the sideboards and adjacent squares to form a chamber. Each treatment consisted of 2 blocks of 24 plants each, with 10 pots used for physical measurements from each treatment.

November 17, 1981, four *Aglaonema* 'Silver Queen' cuttings were stuck per 6-in. standard, white, polypropylene pot containing a medium of peat moss, perlite, and vermiculite in a 2:1:1 ratio by volume. The plants were harvested March 18, 1982, at which time the most developed plants were considered salable. Plants were watered overhead as needed with Dram spray stakes and fertilized with Scotts ProGrow (25-10-10) at the rate of 7 grams per 6-in. pot applied 4 weeks after sticking. Greenhouse light levels were approximately 2000 ft.-c during the experiment.

Temperatures were recorded with an Esterline Angus multipoint recorder equipped with welded copper-constantan thermocouples. Temperatures were measured inside the greenhouse at plant canopy height, in the potting medium, between the pots at sidewall level and outside the greenhouse.

RESULTS

Temperatures were recorded at several positions inside and outside the greenhouse at 7:00 a.m. on February 14, 1982 (Table 1). Bottom heat without a chamber raised the root-zone

temperature appoximately 6°F over that of the control. When a pot chambering system was added, an additional 4 to 5°F was gained in the root zone without additional heat energy input. Temperatures in the soil differed only slightly between the different types of chambers. Temperature at the top of the plant canopy over the heated chambers was about 2°F higher then the canopy temperature of control plots.

Table 1. Influence of bottom heat and chambering systems on soil temperatures in 6-inch pots of *Aglaonema* 'Silver Queen'.

Treatment and location	Temperature[z]	
	°C	°F
No bottom heat (control)		
In pot	18.3	64.9
In chamber	17.9	64.2
Over plant canopy	17.7	63.9
Bottom heat (no chamber)		
In pot	21.5	70.7
Between pots	21.2	70.2
Bottom heat + molded plastic chamber[y]		
In pot	24.4	75.9
In chamber	25.0	77.0
Over plant canopy	19.0	66.2
Bottom heat + strap chamber		
In pot	24.4	75.9
In chamber	25.0	77.0
Bottom heat + pot collar chamber		
In pot	23.7	74.7
In chamber	24.4	75.9
Outside greenhouse	5.2	41.4

[z] Temperatures were recorded 7:00 a.m., 2/14/82 at Melco Nurseries, Inc.
[y] Chambers were manufactured by Kenergy Corporation, Orlando, Florida.

Table 2. Growth of *Aglaonema* 'Silver Queen' as influenced by bottom heating techniques.[z,y]

Treatment	Plant ht. (cm)	Fresh wt. of shoot growth 1 pot (g)	New leaves 1 pot (no.)	Dead and Chlorotic leaves/pot (no.)	Root fresh wt/pot (g)
No bottom heat (control)	36.0	66.7	14.8	0.8	15.1
Bottom heat (no chamber)	38.0	86.5	18.6	2.5	24.3
Bottom heat + molded chamber[x]	42.2	101.5	18.3	1.9	21.3
Bottom heat + strap chamber	37.3	86.0	17.1	2.7	21.5
Bottom heat + pot collar chamber	38.8	95.2	18.8	2.7	24.4

[z] Plants harvested from Melco Nurseries, Inc. and measured 3/18/82.
[y] Values expressed are the means of 10 experimental units from each treatment.
[x] Chambers were manufactured by Kenergy Corporation, Orlando, Florida.

There were differences in shoot and root growth of *Aglaonema* as influenced by the bottom-heated treatments (Table 2). Plants which received supplemental bottom heat had con-

siderably more shoot and root growth than non-bottom-heated plants. They also reached salable size 10 weeks earlier than the control. There was slightly less basal leaf loss on non-bottom-heated plants than those receiving bottom heat.

DISCUSSION

Growth of *Aglaonema* 'Silver Queen' in all bottom-heated plots was significantly greater than that of the control. Lack of growth responses to chambered treatments over the non-chambered, bottom-heated treatment is explained by close pot spacing; wide spreading overlap of plant canopy, which created a chamber, and high ambient greenhouse air temperatures maintained by the backup, forced air heaters. The slightly greater lower leaf loss of bottom-heated plants was due to the increased rate of moisture loss from cuttings before roots penetrated the soil mix.

All pot-chambering techniques examined in this study demonstrated the value of utilizing a chamber of some type to create warmer and more uniform soil temperatures within a containerized potting medium. The ultimate in bottom heating technology will be achieved when chambering techniques permit the grower to maintain the desired combination of temperatures in the root medium and plant canopy for specific crops and stages of the crop cycle. This usually requires one system for bottom heating and another for space heating in greenhouses.

Nurserymen should evaluate growth responses of specific crops to bottom heat before investing in elaborate bottom heating equipment. This can be done on a small scale with electrical resistance heating mats plus a thermostat-thermocouple control unit (9,10).

We feel there is a bright future for refined bottom-heating systems in greenhouses to enhance rooting and growth of selected crops. Emphasis should be given to crops which are: 1) high value; 2) responsive to warm soils; and 3) in demand when growth is slow due to a cool root medium.

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PROPAGATION OF *JUNIPERUS CHINENSIS* 'TORULOSA' USING BOTTOM HEAT

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Abstract. The propagation of torulosa juniper, *Juniperus chinensis* 'Torulosa' (*J. chinensis* 'Kaizuka'), in the Florida climate has long presented a problem. Whether this be a climate problem, stock selection, or procedure, has not in the past been determined to any degree of consistency. However, general opinion seems to suggest that bottom heat would be the most conclusive single factor contributing to successful propagation of this plant. It was fully realized at the onset of this experiment at Tampa Wholesale Nursery that bottom heating was not a new process, neither were we pioneering any radically new or innovative techniques for providing the heat. The specific purpose was to design and implement a system that would provide a functional, economical means of producing liners for this operation, as well as to add to existing knowledge of techniques and procedures for propagation of this plant.

REVIEW OF LITERATURE

Determinations of the overall system design were done by evaluating information provided by Dr. R. W. Henley, Extension Specialist in the Ornamental Horticulture Department of the University of Florida, evaluating written descriptions of other existing systems, and from personally evaluating existing operating systems. Initial concerns were that the system design and function be developed in direct coordination with physical facilities into which it was to be built. In addition, this system

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must be designed to be monitored effectively as it related to all aspects of the physical environment in which it was to exist.

MATERIALS AND METHODS

The area selected for installation of this experiment was inside a fiberglass propagation structure, fan cooled and gas heated. The size of the structure to be heated was 6 × 30 ft. (one standard nursery greenhouse bench). Provisions were made during all phases of design and construction to provide for additional benches to be added to the system if so desired.

For maximum heat economy the heating grid was installed in a medium directly on the greenhouse floor. A wood frame, 6-in. deep, enclosed the area to be heated and was lined with 4 mil poly. This area was then filled with ground aggregate rock to a depth of 4 in. The aggregate was watered and tamped to a firm smooth surface. After reviewing the various tube materials available for hot water distribution, black polyethylene was chosen. Later analysis of all factors considered will show that this was probably not the most advantageous material as the metal clamps needed to hold it in place were expensive and difficult to install. However, for the purpose of this experimental stage it served well; ¾ in. size was installed directly on the top of the aggregate by clamping the tube to wood stringers placed 24 in. apart. Heated water was introduced into opposing corners of the grid and woven through the bed in alternating coils to insure even heat distribution. The coils were spaced 6 in. apart then covered with 1 in. of aggregate. Figure 1 shows the grid system as installed.

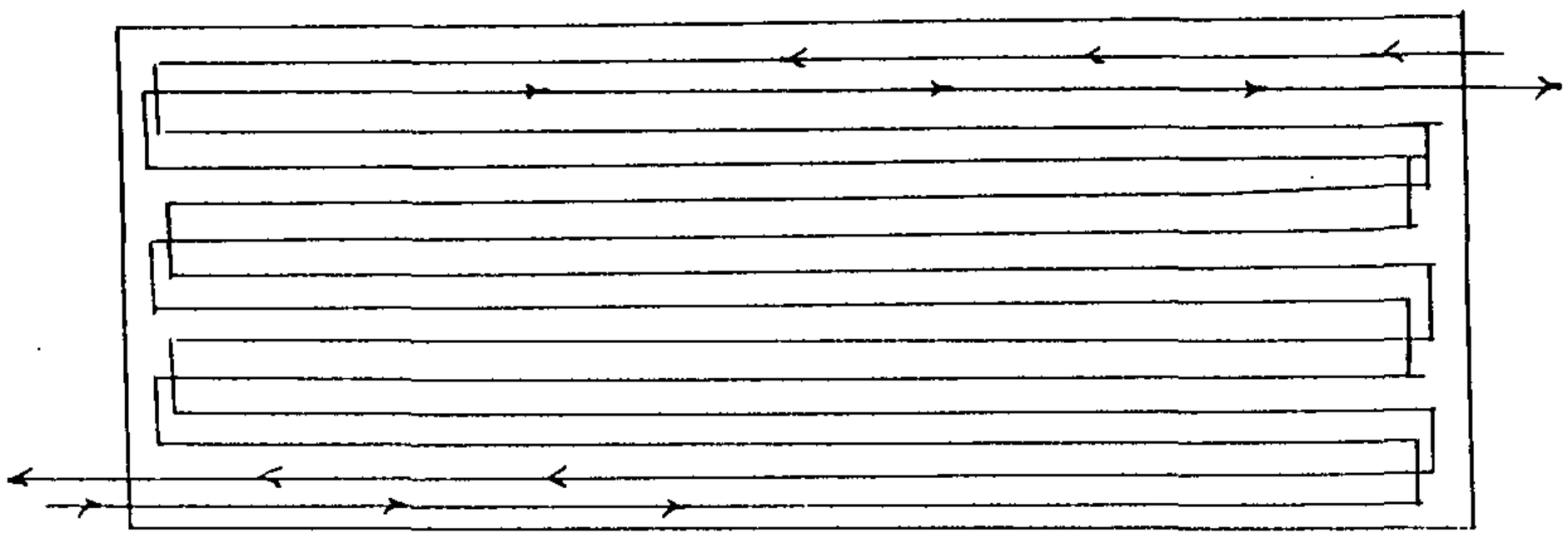
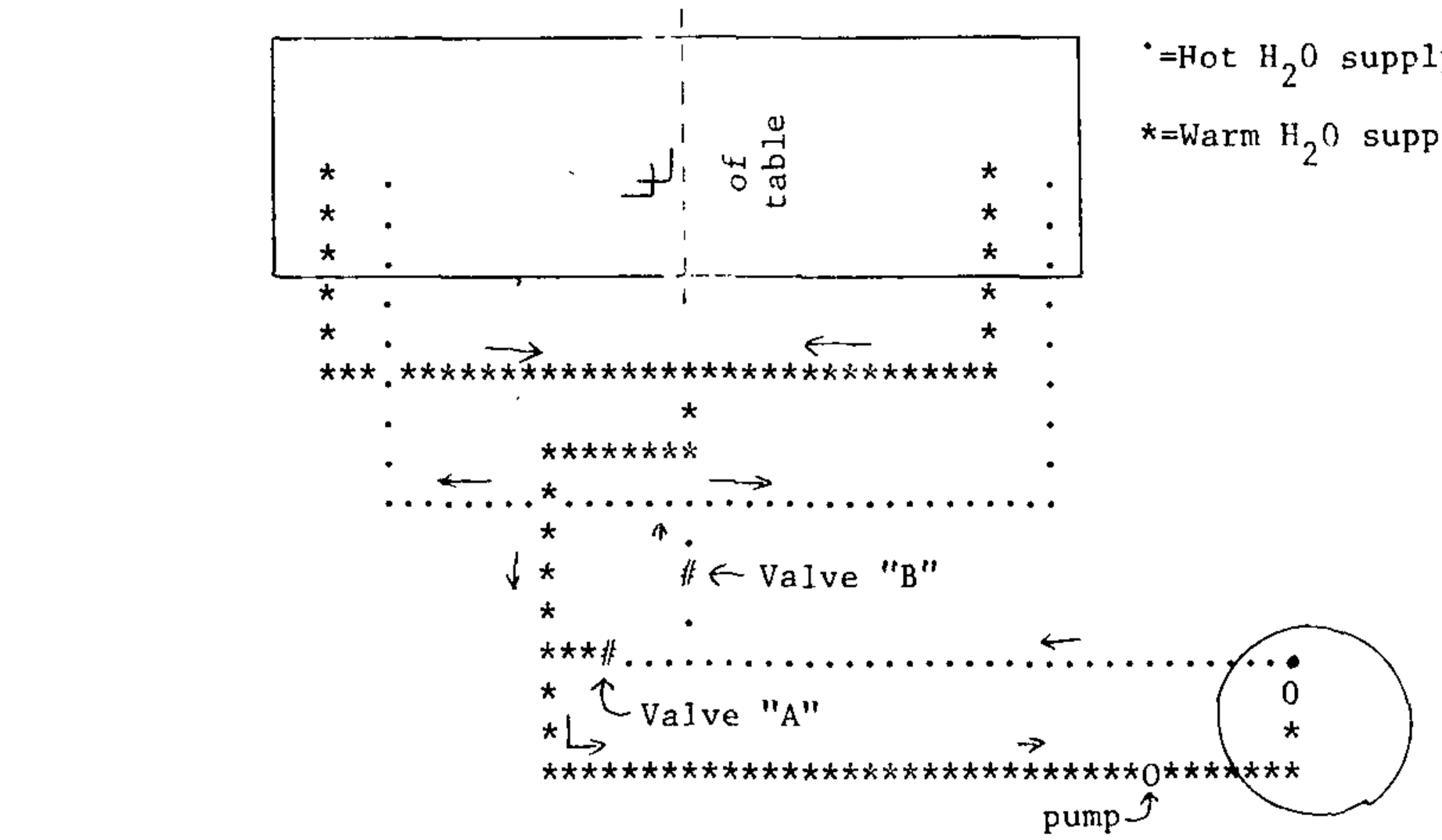


Figure 1. Heating Grid

The water-heating unit used was a 75-gal. standard home, 2-element electric water heater. Modification was made to insure proper pressure release at 15 psi. Electric clocks were connected to each element to monitor total heating time.



Valve "A" - 3/4" solinoid 120V
Valve "B" - 3/4" solinoid 120V

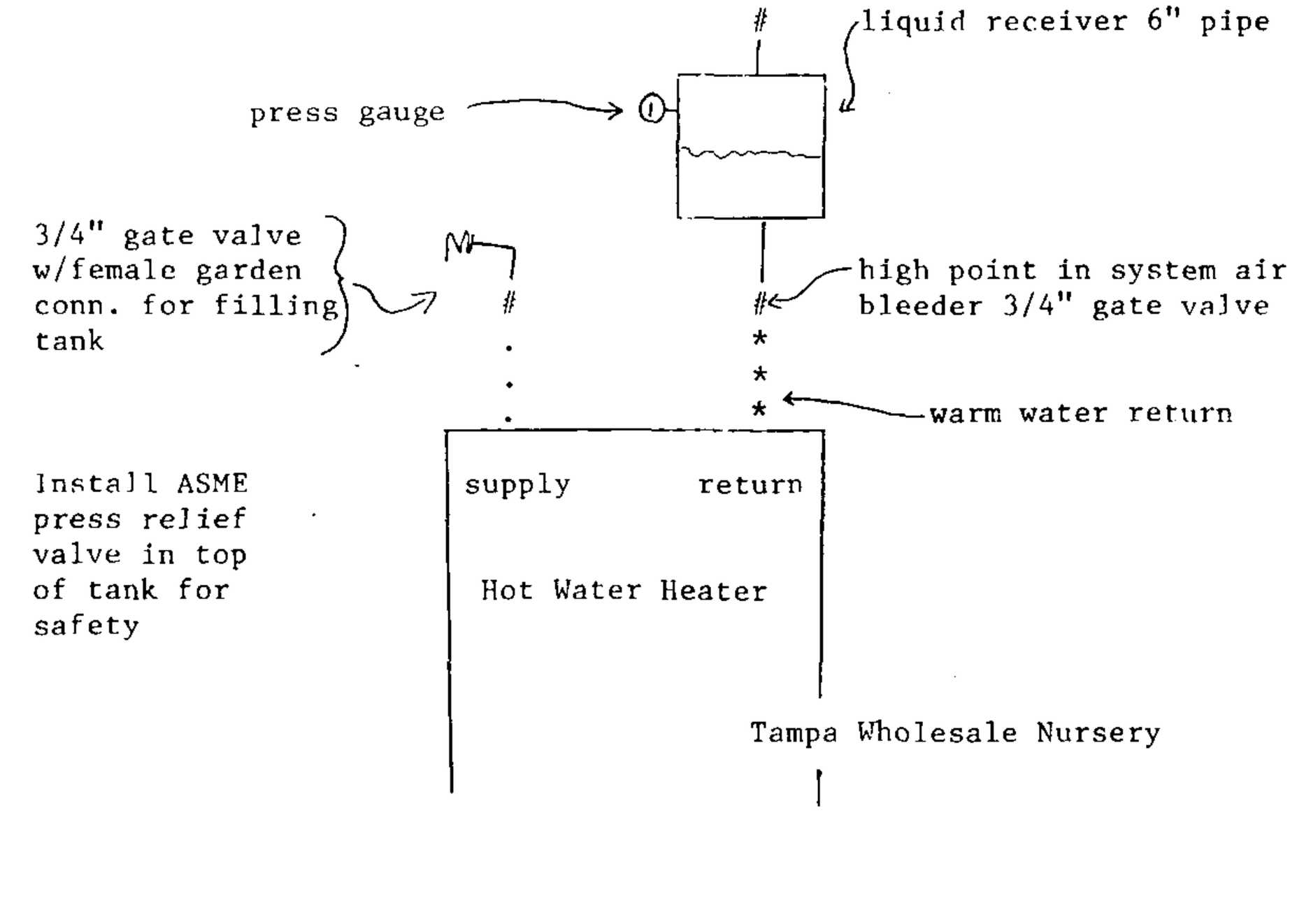


Figure 2. Circulation System

Figure 2 shows the circulation system. The water-circulation pump is located on the return line immediately prior to entering the heating unit. The pump runs continuously as water circulation to the grid is controlled by a two-story switching relay. The switching mechanism reacts to the thermocouple placed directly in the bench material. Bench temperature was calibrated to maintain 70° to 76°F at mid-tray level in the propagation flats.

Since this was a closed circulation system, it was necessary to locate an air collection-release tank atop the heating tank at the highest point in the system. Gate valves above and below the collection tank allow for air release without opening the circulation system.

Two-thousand torulosa juniper cuttings were stuck on January 21, 1983. Cutting wood was selected from nursery stock material in 15-gal. containers. Cuttings were made from tips of lateral branches. Experimental and control groups were both dipped in a solution of captain and Benlate (benomyl), then treated by dipping the lower 1½ in. of stems in Hormodin 2 powder. The control group was situated immediately alongside the heated bench. All factors of light, ambient air temperature, and air circulation were maintained compatible on both groups. As the experiment progressed, it was noted that approximately 50% more moisture was required on the heated bench to maintain appropriate wetness.

Temperature in the heated bench was maintained at 74° to 78°F. The control bench temperature changed as the ambient air temperature in the greenhouse changed. Figure 3 shows recorded temperatures.

RESULTS AND DISCUSSION

First sign of callusing was noted on the heated bench on the 13th day. First root initiation was noted on the 22nd day. No callusing or root initiation was noted in the control group on these dates. Rooted cuttings were removed from the heated bench on the 45th day and random trays counted for sampling; 92% of the cuttings in the experimental group were counted as rooted sufficiently for removal and potting as liners. None of the cuttings in the control group was sufficiently rooted for potting at the time (Figure 4).

Additional energy cost for operating this system during this period was computed to be appoximately 1.4 cents per plant. Based on the return temperature of the water, a relatively small additional amount of energy would be required to extend the capacity of this system to at least 300% the present capacity.

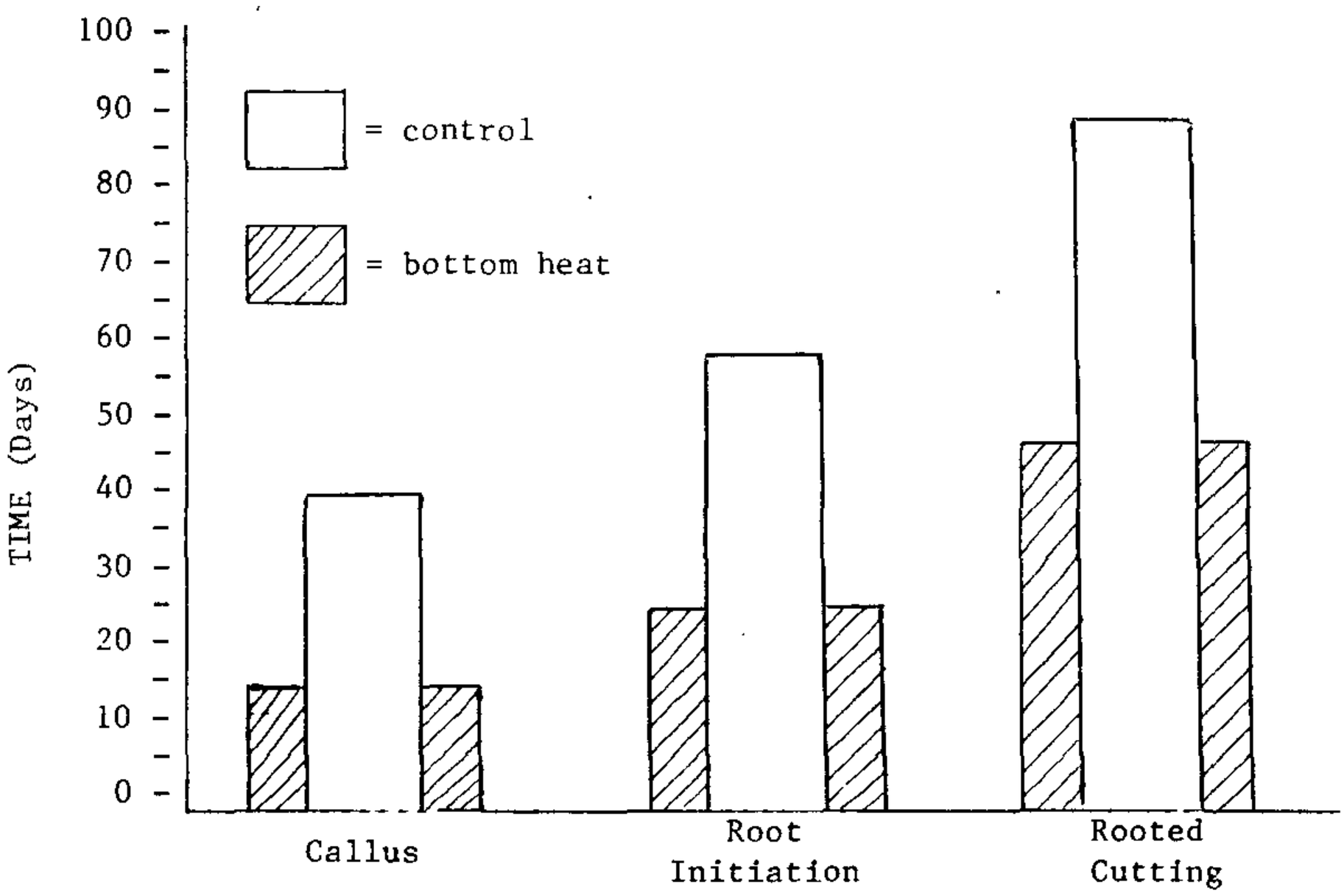


Figure 3. Time of callus, root initiation, and rooted cutting of torulosa juniper.

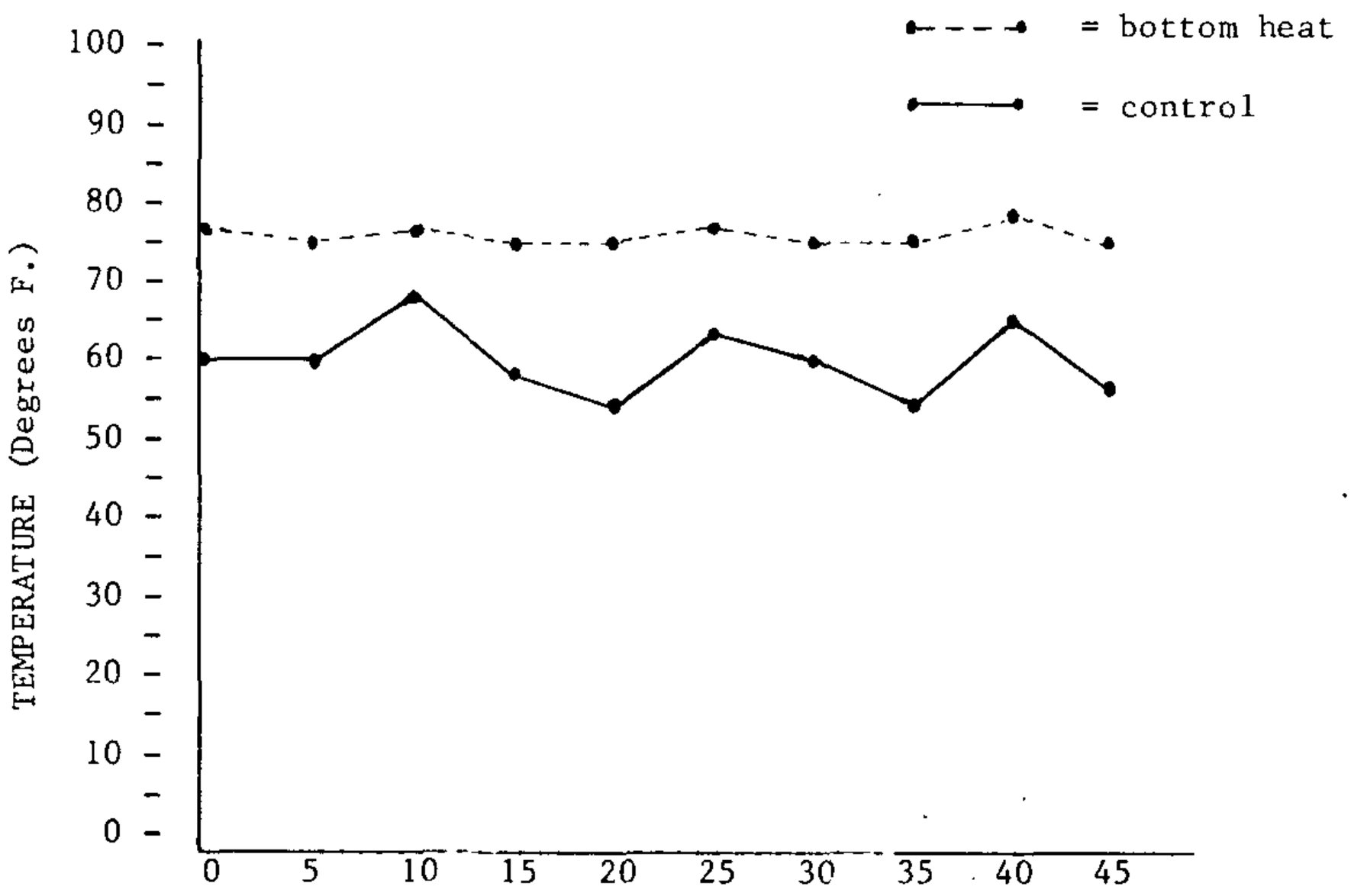


Figure 4. Soil temperatures recorded at 8:00 a.m.

We can conclude most definitely that bottom heat provided faster rooting and a higher percent of take. Considering the relatively short period required and the low cost per plant produced, bottom heat is an economical approach. The rooted cuttings produced under bottom heat conditions showed better health and growth with very little die-back, leading to a better quality plant.

LITERATURED CITED

1. Henley, R. W. 1982. Warm water heating soil in greenhouses in Florida. *Southern Florist and Nurseryman* 95(33):9.
2. Henley, R. W., Roger Newton, and Don Todd. 1982. An in-house evaluation of bottom-heat by a commercial greenhouse operator. *Foliage Digest.* 5(11):45.

BIOTHERM BOTTOM HEATING IN PROPAGATION

TED SPRINGER

Biotherm Engineering
611 Mountain View Avenue
Petaluma, California 94952

Bottom heating is not a new idea. Fifty years ago steam-heated greenhouses were heated from the ground up. Today we are returning to that method as it becomes more and more critical to use energy in the most efficient way possible. Now, however, we are interested in the number of cubic feet actually heated as well as in minimizing the level of heat used. We are interested in the transfer of low-grade heat. The Biotherm system does this by using hot water as the heat carrier. We do not need or want high temperatures in our growing benches. One mum grower quite accidentally discovered the advantages of bottom heat when he left his Modine unit on the floor following a tornado. He began to notice increased plant growth, which dramatically illustrated what we have known all along: soil temperature is what counts! For many plants a 70°F thermostat setting will give a good crop. But this is head high! It is not the same with bottom heat. Check the soil temperature where the best plant is growing to determine what a 70°F degree thermostat setting really means. Different containers and media affect the gradient between air and root-zone temperatures but, in general, the difference is around 10°F.

What we want, then, is to reduce energy requirements by minimizing the heat level and space heated. What is extremely

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What we want, then, is to reduce energy requirements by minimizing the heat level and space heated. What is extremely

important is that in doing so we provide maximum temperature uniformity. Only then can the bottom-heat technique become an efficient part of an overall, automated production system, which is the only way to achieve economic efficiency. Remember, any time one component of a system is changed, all others must be adjusted as well. The plants will not automatically adapt; management practices must be re-evaluated and changed if necessary.

One of the most important reasons for insisting on even heat distribution is that watering requirements throughout a crop are then the same, provided containers and medium are the same. Effective automatic watering is impossible unless this is true. The Biotherm is laid on 2-in. centers. With this spacing it is possible to maintain even heating through a single tray or between separate containers on the bench without burning it. We do not suggest putting a capillary mat over the tubes when plug trays are used. With such close spacing it is important that no bench space is sacrificed for the tubing itself. Yet to maximize energy utilization we wanted to avoid burying the tubes. Although the tubing does not collapse even when heavy containers are set on it, it is usually more convenient to lay welded wire on top of the tubes. When the tubes are buried, heat transfer is limited not by the temperature of the water but by the heat transfer coefficient of the material in which it is buried. Even the new porous cement cuts down efficiency tremendously. To give some idea of what this means, the maximum amount of heat energy that porous concrete can put out is 25 BTU/ft^2, or about half of what is needed in a double-layered poly house when outside temperature is 0°F. With uncovered tubing, it is also possible to provide microclimate as well as soil temperature control by allowing more actual heat transfer from the system into the growing environment.

We looked at many different materials before deciding on one. It is an ethylene propalene diamine material that is similar to neoprene with a temperature range of 50° to 300°F. It is resistant to almost anything but petroleum oil compounds. It is flexible, and it is important to allow for expansion when it is filled with warm water. A flexible connecting hose can take care of this slack. All headers and connections can be put under or outside the end of the bench to avoid loss of growing space. At first, fastening all of this footage of tubing to the benches seemed impossibly time consuming. We have now developed a type of nylon material, which we call a tube-gribber, that can actually hold the tubes in place without screwing down clamps.

By using this type of bottom heating it is possible to take advantage of newer production systems much more effectively. In addition to improving automatic watering results, the flexible hose and connection makes it possible to use rolling or removable benches quite easily. Remember that with any production routine it is important to evaluate each part and determine how well a new segment will fit into the whole. This must be done on an individual basis. Test a system such as Biotherm first on a small basis. By so doing, much can be learned to make complete installation and management much easier and much more profitable.

CHLORINATION OF IRRIGATION WATER

BILL DAUGHTRY

Lancaster Farms, Inc.
5800 Knotts Neck Road
Suffolk, Virginia 23435

Our nursery is a container operation where we place all of our containers on polyethylene. Most of our beds drain into one of our ponds, along with any pathogens that are washed out of the containers. Therefore, recycling the water will distribute these pathogens over the entire nursery. While researching this problem, we found that many pathogens may be inherent in the water supply and that recycling the water can only increase the problem. Before considering chlorination, have the water tested to make sure that it is part of the problem.

Chlorine compounds have been used for the disinfection of water for 100 years, but how it works is still not fully understood. We chose the injection of Cl_2 gas as our method of chlorination.

The element chlorine exists as a gas at room temperature. It has a characteristic pungent odor, which can be detected at extremely low concentrations. It is greenish-yellow in color, 2½ times as heavy as air, and will seek the lowest point in the building if a leak occurs. Chlorine is neither explosive nor flammable but will support combustion. It is reactive with almost all elements and will form many inorganic and organic compounds. Dry chlorine (Cl_2 in the presence of less than 150 ppm H_2O) does not react with most metals, but in the presence of moisture it becomes highly corrosive. When chlorine gas is compressed, it forms a clear, amber-colored oily fluid that is

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1½ times as heavy as water. As the liquid vaporizes, its volume increases 460 times. Chlorine gas at low concentrations is primarily a respiratory irritant. In sufficient concentrations it will also irritate mucous membranes and skin. At high concentrations it can cause death from lack of oxygen in the air or from lung damage.

Chlorine gas is supplied in pressurized cylinders that are appoximately 80% liquid and 20% gas. Pressure in the cylinder provides no indication of the weight of the remaining liquid chlorine. It will remain steady until all of the liquid has been vaporized as long as the temperature is constant. The rate of flow of Cl_2 from a cylinder is only as rapid as the rate at which the liquid can be vaporized. This is temperature dependent. As the temperature increases, the pressure and rate of flow will increase. At ambient temperatures the rate of flow from a 150-lb. cylinder is appoximately 1.75 lbs. per hour and from a one-ton cylinder is 15 lbs. per hour.

When chlorine is mixed with water, it quickly hydrolyzes to form hydrochloric and hypochlorous acids.

$$Cl_2(g) + H_2O(liq) \rightleftharpoons HCl(aq) + HOCl(aq)$$

The hydrochloric acid concentration is extremely low and has a negligible effect on pH. The hypochlorous acid will partially dissociate to form hydrogen and hypochlorite ions.

$$HOCl \rightleftharpoons H^+ (aq) + OCl^- (aq)$$

The level of this reaction is controlled by the pH of the water. At a pH of 6.0 or below, HOCl is present. As the pH increases, the reaction shifts toward the formation of OCl^- until at pH 9.0 the HOCl is almost totally dissociated. As a disinfectant, HOCl is 80 times more active than OCl^-. Irrigation water normally is in a pH range that will keep the HOCl from dissociating significantly.

The total quantity of chlorine in the three forms Cl_2, HOCl, OCl^- are called free residual chlorine or free available chlorine (F.A.C.).

The difference between the amount of Cl_2 added to a given quantity of H_2O and the amount of F.A.C. remaining at the end of a given contact period is referred to as the Cl_2 demand. This chlorine has been tied up by reacting with any impurities in the water: organic matter, fertilizers, colloidal materials, etc.

Ammonia (NH_3) has the most influence upon the chemistry of H_2O chlorination. The reaction of Cl_2 and NH_3 is not

instantaneous but requires up to one minute for completion, depending upon the pH and temperature. During this initial delay the F.A.C. is being rapidly reduced, but an enhanced rate of disinfection occurs because of the initially elevated levels of F.A.C. During this brief period many pathogens that concern us are controlled. The 30-minute to 2-hour contact time indicated in available literature for the decontamination of industrial waste water and sewage effluents may not be necessary to obtain relatively clean irrigation water.

After several attempts at injecting various chlorinated materials that were expensive, highly corrosive, and labor intensive to mix and regulate, we decided to use chlorine gas. Chlorine gas is extremely dangerous, so we purchased what we still think is the safest injector available. We bought a series V500-remote vacuum chlorinator manufactured by Wallace & Tiernan, a division of the Pennwalt Corporation, 25 Main Street, Belleville, N.J. 07019

There were several reasons for this purchase. The Cl_2 is maintained in the system under a vacuum; it will signal when the cylinder is empty and Pennwalt has the technical support to help install, operate and maintain the equipment.

We are on a constant fertilization program. When the Cl_2 that has been injected comes in contact with the fertilizer, the Cl_2 is almost immediately tied up. To increase our contact time, we take a 1-in. water line from the pressure side of our pump and treat it with a high concentration of chlorine. This chlorinated water is piped into the lake. The water is dispersed through a header 18 in. long with ¼-in. holes 1 in. apart. The header is slightly above and 1 ft. in front of the intake screen. The chlorinated H_2O and lake H_2O are mixed as they are drawn into the suction line. Our contact time is the time the water takes to move from that point to where our fertilizer is injected, which is approximately 15 sec.

To achieve maximum control, enough chlorine gas must be injected to obtain an F.A.C. reading. We try to maintain a level of 0.3 ppm (or 0.3 mg/l) F.A.C. Our chlorine testing is carried out with a simple swimming pool test kit that is based on the D.P.D. (diethyl-phenylene-diamine) chlorimetric method. Kits are also available which use the o-tolidine method, but these are not considered as accurate.

Tests have shown that we can control the motile spores of *Pythium* and *Phytophthora* and greatly decrease our population of bacteria. We cannot prove any other benefits, but we no longer have *Fusarium* leaf spot on 'Hershey Red' azaleas, and we are now controlling *Rhizoctonia* with our normal 30-day spray program.

This year we used nine 150-lb. cylinders of chlorine. Our total cost of this 1,350 lbs. was $371.67, including demurrage of tanks and delivery. We treated approximately 35 million gal. of water. The same amount of Cl_2 purchased as calcium hypochlorite under the trade name of H.T.H. would cost $2,065.50. We purchased three Cl_2 injectors @ $2,100.00 each. Without considering the difference in the labor and equipment required to mix H.T.H. (which is considerable), the return on our investment would still be only 3 years.

Safety should always be considered when handling Cl_2. Several rules should be followed:

1. Secure tanks in an upright position.

2. Never change a tank alone.

3. Have available a full-face respirator with the Cl_2 canister or have an independent air supply.

4. Always use new lead gaskets when connecting tanks.

5. Check all connections with concentrated NH_3 solution. Household NH_3 is not strong enough. A leak will look like cigarette smoke.

6. Have protective caps in place when moving tanks.

The installation of equipment and use of chlorine gas has become an efficient and effective means of controlling waterborne diseases at Lancaster Farms.

INFLUENCE OF CHEMICAL SANITATION TREATMENTS ON PROPAGATION OF *BUXUS MICROPHYLLA* AND *PEPEROMIA CAPERATA*

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Abstract. Rooting of Japanese boxwood and peperomia shoot cuttings was used to determine the influence of chemical treatment procedures on propagation efficiency of two widely planted nursery and greenhouse crops. In the first experiment 10 commercial fungicides and a disinfectant[1] were applied as drench and cutting soak treatments to boxwood, *Buxus microphylla* var. *japonica*, cuttings which were rooted in a steam sterilized mist bench. Lesan© 70W applied as a soak was the only treatment that inhibited rooting of boxwood cuttings when compared to cuttings not receiving chemical treatment. Cuttings treated with drench or soaks using Terraclor© 75W or drenches using Banrot© 40W produced more roots than control, but in root length, number of roots, and root weight, the treatments could not be separated from results with untreated cuttings. Root numbers of cuttings treated with drench applications of Lesan 70W, Subdue© 2E, Banrot 40W, and Terraclor 75W were greater than with soak treatments using the fungicides. In a second study the influence of soil fungicide treatments on rooting of *Peperomia caperata* 'Blackie' leaf cuttings was determined in a peat/perlite growing medium receiving periodic manual watering. Rooting percentage of untreated leaf cuttings was equal to or better than that of cuttings receiving chemical treatment application. Root development of cuttings receiving Agrimycin© 21W, Benlate© 50@, Subdue 2E, and combinations of Subdue 5W + Benlate 50W, and Truban© 5G + Benlate 50W Agrimycin 21W, was greater than control. In general, however, rooting percentage and root development was restricted when combinations of chemicals were applied to cuttings. Treatments using the fungicides Terraclor 75W and Captan© 50W gave consistently poor results, suggesting phytotoxicity.

REVIEW OF LITERATURE

Diseases occurring on propagative units are a common source of soil-borne pathogens at the initiation of the growing cycle. This situation can largely be attributed to inadequate use of sanitary production practices during propagation (1).

Regardless of the growing medium used for vegetative propagation, disinfestation is highly desirable to eliminate weeds, insects, nematodes, and disease organisms (1,3). Aerated steam sterilization was developed in an attempt to reduce the problem of pathogen re-entry (2); however, the treatment has little effect on pathogens introduced on shoot cuttings. For this reason, chemical disinfectants are frequently employed as

[1] Trade names and company names are included for the benefit of the reader and do not imply endorsement or preferential treatment of the products listed by Texas A&M University.

an additional tool for controlling diseases in the propagation bench (1). Cuttings of woody ornamental plants in a mist bench are susceptible to attack by several species of *Pythium*, *Phytophthora*, *Rhizoctonia*, (12), *Fusarium* (10), *Botrytis* (5), *Alternaria*, *Cylindrocladium*, *Gloesporium*, *Pestalotia* (11), and other pathogenic fungi. Several of the more popular fungicide formulations, including Benlate© (4), thiram (6), captan (7), Difolatan© (11), Subdue and Truban© (9), have been cited as phytotoxic to cuttings in mist propagation. Other reports indicate enhanced rooting of cuttings treated with Ferbam© (8, 13), thiram (8), and combinations of fungicides and growth regulators (8). A wide range of chemical disinfectants is available for prevention of soil-borne problems, yet few studies have been conducted to determine the influence of chemical sanitation programs on propagation efficiency.

MATERIALS AND METHODS

Experiment I — Influence of Chemical Disinfectants on Boxwood Propagation Efficiency

Studies were designed to determine the effects of several disinfectant treatments on rooting efficiency of Japanese boxwood, propagated under mist. We evaluated 10 commercially available fungicides and a disinfectant (commercial bleach) for phytotoxicity, both as a dip and drench application during the propagation cycle.

Uniform 10 cm length stem tip cuttings bearing six leaves were collected from a single Japanese boxwood hedge in July, 1981. Basal tips of the cuttings were dipped for 5 seconds in an aqueous solution of 10 g/l 3-indolebutyric acid (potassium salt), and allowed to dry for approximately one minute. Chemical disinfectants were then applied directly to cuttings as a 3-min. soak prior to planting or to the propagation medium as a drench, at rates and frequency of application suggested by the manufacturer (Table 1). The cuttings were placed at a depth of 5 cm in a steam-sterilized propagation medium consisting of perlite-peat moss 3:1 (v/v) under intermittent mist. Cuttings were arranged in a randomized complete block design with three replications of 10 cuttings per replication. Data were collected after 43 days, at which time the untreated control cuttings had rooted. Parameters measured were: (1) percentage rooting of cuttings, (2) total number of roots per cutting, (3) root weights per cutting, and (4) root lengths as determined by the means of lengths of the three longest roots per cutting. All data were subjected to square root transformation after which they were analyzed using an analysis of variance and Duncan's multiple range test. Means reported in Table 3 were computed from untransformed values.

Table 1. Fungicides, methods of use, and frequency of application to cuttings of *Buxus microphylla* var. *japonica*[a].

Chemical formulation	Rate (oz/100 gal.)	Method of applicaton[b]	Application Frequency
Control, not treated			
Truban 5G	10 oz/yd^3	Medium incorporation	Preplant
Truban 30W	8 oz	Soak	Preplant
Truban 30W	8 oz	Drench	1, 34 days
Truban 25E	8 oz	Soak	Preplant
Truban 25E	8 oz	Drench	1, 34 days
Lesan 70W	8 oz	Soak	Preplant
Lesan 70W	8 oz	Drench	1,12,22,34 days
Captan 50W	24 oz	Soak	Preplant
Captan 50W	24 oz	Drench	1,12,22,34 days
Subdue 2E	0.8 oz	Soak	Preplant
Subdue 2E	0.8 oz	Drench	1,34 days
Benlate 50W	8 oz	Soak	Preplant
Benlate 50W	8 oz	Drench	1,12,22,34 days
Banrot 40W	12 oz	Soak	Preplant
Banrot 40W	12 oz	Drench	1, 34 days
Dithane M-45 80W	32 oz	Soak	Preplant
Dithane M-45 80W	32 oz	Drench	1, 34 days
Terraclor 75W	4 oz	Soak	Preplant
Terraclor 75W	4 oz	Drench	1st day only
Clorox	10%	Soak	Preplant
Clorox	10%	Drench	1,12,22,34 days

[a] Preplant soak of cuttings was for 3 min. Drenches were applied to cuttings and medium at a volume of 1.5 pints/ft^2 of bench space.

[b] Chemical names of these fungicides are:

Truban:	5-ethoxy-3-trichloromethyl-1,2,4-thiodiazole
Lesan:	sodium (4-dimethylamino) phenyl) diazene sulfonate
Subdue:	N-(2,6-dimethylphenyl)-N-(methoxyacetyl)-alanine methyl ester
Benlate:	methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate
Banrot:	5-ethoxy-3-trichloromethyl-1,2,4-thiodiazole, 15%, dimethyl 4,4-0-phenylenebis (3-thioallophanate), 25%; and inert ingredients, 60%
Captan:	cis-N-(trichloromethyl) thio)-4-cyclohexene-1,2-dicarboximide
Dithane M-45:	manganese ethylenebisdithiocarbamate
Terraclor:	pentachloronitrobenzene

Experiment II — Influence of Chemical Treatment on Propagation Efficiency of *Peperomia caperata.*

Leaf cuttings of *Peperomia caperata* 'Blackie' were placed in a peat moss-perlite growing medium (1:1 v/v) adjusted to pH 6.7 with hydrated lime. Fungicides used in the study were applied as a drench following planting, or incorporated into the growing medium prior to planting at use rates suggested by the manufacturer (Table 2). The volume of application used for drench treatments was 709 ml (1.5 pints)/sq ft. Following planting and application of chemical treatments, the cuttings

received watering and fertilizer with solutions containing Peters 20-19-18 (20N-8.2P-14.9K) three times per week. After 44 days, 10 cuttings from each treatment were washed in running water to remove growing medium from the root system. Percentage rooting of the cuttings and visual assessments of root development using a root index are reported.

Table 2. Chemical products, use rate, and method of application for rooting studies with *Peperomia caperata* 'Blackie'

Chemical formulation	Rate of applicaton (oz/100 gal)*	Method of application**
Truban 5G	10 oz/yd^3	Medium Incorporation
Truban 30W	8 oz	Soil drench
Truban 25E	8 oz	Soil drench
Banrot 40W	12 oz	Soil drench
Subdue 5W	2.5 oz	Soil drench
Agrimycin 21W	16 oz	Soil drench
Lesan 70W	8 oz	Soil drench
Benlate 50W	8 oz	Soil drench
Terraclor 75W	4 oz	Soil drench
Captan 50W	24 oz	Soil drench

* Chemical combinations were used at rates indicated for each.
** Chemical drench applications were applied after planting at a volume of 1.5 pints/ft^2 of propagation medium.

RESULTS

Experiment I — Boxwood Propagation Efficiency

General comments: Lesan 70W, used as a preplant cutting soak, was the only treatment tested that inhibited rooting as compared with the untreated control (Table 3). In all parameters evaluated, cuttings treated with Lesan 70W drench developed better roots than did cuttings treated with similar rates of Lesan 70W soak, yet the effects of Lesan drench on rooting (all parameters) could not be separated from control.

Cuttings treated with Terraclor 75W consistently provided roots equal to or greater than nontreated cuttings. Cuttings treated wtih commercial bleach, in both drench and soak applications, rooted equal to control. Applications of Benlate and captan, which in other reports (5, 7) inhibited rooting or ornamental plants of several species, did not inhibit rooting in boxwood, compared with control, as either drench or soak.

Ferbam (ferric dimethyldithiodicarbamate) reportedly stimulated rooting in cuttings of *Hevea brasiliensis* (13) and *Hebe diosmilofia* (8), due possibly to its auxin-like activity, but Manzate 200, also a dithiodicarbamate fungicide, did not enhance rooting of *Buxus* cuttings. No particular class of compounds appeared to be more or less phytotoxic than any other.

Table 3. Rooting under mist of *Buxus microphylla* var. *japonica* treated with fungicides[1].

Treatment	No. roots	Root length (mm)	Percent rooting	Root wt/cutting (g)
Control	13.4 bcdef	18.5 abcd	87 ab	0.16 ab
Truban 30W				
drench	16.1 ab	13.5 cd	93 a	0.14 ab
soak	14.4 bcde	14.0	83 ab	0.19 ab
Truban 5G				
in medium	8.4 efg	14.2 de	76 ab	0.11 ab
Truban 25E				
drench	13.3 bcdef	13.6 cde	87 ab	0.15 ab
soak	9.7	23.4 abc	83 ab	0.16 ab
Lesan 70W				
drench	14.7 abc	16.1 bcd	93 a	0.19 a
soak	7.4 g	1.00 e	57 b	0.08 b
Subdue 2E				
drench	15.5 abc	25.0 ab	97 a	0.20 a
soak	7.8 efg	19.2 bcd	80 ab	0.11 ab
Benlate 50W				
drench	9.2 defg	20.2 bcd	80 ab	0.12 ab
soak	10.4 bcdefg	19.6 abcd	90 ab	0.12 ab
Banrot 40W				
drench	15.1 ab	22.5 ab	100 a	0.20 a
soak	7.2 fg	19.4 abcd	80 ab	0.11 ab
Captan 50W				
drench	10.6 bcdefg	19.8 abcd	90 ab	0.15 ab
soak	10.8 bcdefg	22.5 abc	90 ab	0.17 ab
Manzate 200				
drench	11.8 bcdef	20.4 abc	93 a	0.17 ab
soak	11.3 bcdefg	19.6 bcd	73 ab	0.18 ab
Terraclor 75W				
drench	20.9 a	25.7 a	100 a	0.21 a
soak	10.5 bcdefg	25.7 a	100 a	0.16 ab
Clorox 1:10				
drench	14.5 bcd	15.7 bcd	87 ab	0.14
soak	10.5 bcdefg	22.0 abc	87 ab	0.19 ab

[1] Mean separation within columns by Duncan's multiple range test, 5% level.

Greater numbers of roots developed on cuttings drenched with Lesan, Subdue, Banrot, and Terraclor than appeared on cuttings soaked in those materials. This might be attributable to accumulative effects of multiple applications of the treatment as opposed to single soil applications, except with Terraclor which was drenched only once at the beginning of the experiment (Table 1).

Number of roots: Terraclor 75W drenching enhanced rooting, and Lesan 70W soak had an inhibitory effect, compared with control. None of the other treatments could be separated from control. Lesan 70W, Subdue 42E, Banrot 40W, and Terraclor 75W applied as drench applications resulted in greater

rooting than did these fungicides when applied as soak applications.

Root length: Use of Lesan 70W as a soak resulted in shorter roots than untreated control cuttings and cuttings receiving 18 other treatments, including Lesan 70W drench. None of the other treatments could be separated from control, although greater root lengths occured in cuttings treated with both Terraclor 75W drench and soak than with 10 other fungicide treatments.

Root weight and percent rooting: Treatments did not significantly influence root weight or percent rooting, when compared to the control.

Experiment II — *Peperomia caperata 'Blackie'* Propagation Efficiency

Of 34 chemical sanitation measures used for rooting of *Peperomia* 'Blackie' leaf cuttings, reductions in percent rooting of leaves were observed for 13 treatments tested (Table 4). Rooting percent was equal to untreated leaves (100%) in 21 sanitation treatments used in the study. Percent rooting of treated leaves did not appear to be influenced by the use of singly applied or combinations of chemicals used for treatment; however, Captan 50W, Terraclor 75W, Banrot 40W, and Truban 25E when applied singly resulted in a reduction in rooted leaf cuttings compared to control. Use of Agrimycin© 21W, Lesan 70W, Benlate© 50W, Subdue 5W, Truban 30W, or Truban 5G gave rooting percentages equal to untreated control leaves. Root development of leaf cuttings 44 days after planting appeared to be influenced by both type and number of chemicals used for sanitation during propagation. Only 6 of 24 combination treatments tested resulted in root development indices greater than untreated leaf cuttings while 8 of 10 singularly applied chemical treatments gave a root development rating greater than untreated leaves. Four single chemical treatments including Agrimycin 21W, Lesan 70W, Benlate 50W, and Subdue 5W had root development indices significantly greater than untreated control values. Combination chemical treatments using Subdue 5W + Benlate 50W and Truban 5G + Benlate 50W + Agrimycin 21W also gave significantly greater root development than untreated cuttings.

DISCUSSION

In the present investigation, use of four parameters for measuring rooting activity of boxwood cuttings exposed to 22 chemical treatments gave statistical differences in only one parameter (root number/cutting) for two of the treatments

tested. With the exception of Lesan 70W used as a 10 min soak, where root length and number on boxwood cuttings were significantly reduced, there appears to be no deleterious effect of the chemical treatments tested.

Table 4. Influence of single-application soil fungicide treatments on rooting of *Peperomia caperata* 'Blackie' leaf cuttings*.

Fungicide treatment	Mean percent rooting	Mean root** development (Index 0-5)
Subdue 5W + Benlate 50W	100	4.30 a
Agrimycin 21W	100	4.10 ab
Lesan 70W	100	3.90 abc
Truban 5G + Benlate 50W + Agrimycin 21W	100	3.80 abc
Benlate 50W	100	3.80 abc
Subdue 5W	100	3.60 abcd
Truban 30W + Benlate 50W + Agrimycin 21W	100	3.05 bcde
Truban 30W	100	3.00 bcde
Truban 25E + Benlate 50W	90	2.95 cde
Truban 25E + Benlate 50W + Agrimycin 21W	100	2.83 cde
Banrot 40W	90	2.80 cde
Truban 5G	100	2.60 de
Truban 25E	90	2.55 de
Truban 5G + Benlate 50W	100	2.30 ef
Not Treated, Control	100	2.20 ef
Subdue 5W + Benlate 50W + Agrimycin 21W	100	2.20 f
Truban 25E + Terraclor 75W + Agrimycin 21W	100	1.38 fg
Truban 30W + Benlate 50W	100	1.35 fg
Truban 5G + Terraclor 75W	100	1.35 fg
Subdue 5W + Terraclor 75W	100	1.30 fg
Subdue 5W + Terraclor 75W + Agrimycin 21W	90	1.20 fg
Truban 5G + Terraclor 75W + Agrimycin 21W	100	1.05 g
Lesan 70W + Terraclor 75W	100	1.00 g
Truban 30 + Terraclor 75W + Agrimycin 21W	80	1.00 g
Lesan 70W + Benlate 50W + Agrimycin 21W	90	0.90 g
Terraclor 75W + Captan 50W + Agrimycin 21W	70	0.65 g
Lesan 70W + Benlate 50W	50	0.65 g
Truban 30W + Terraclor 75W	80	0.60 g
Terraclor 75W + Captan 50W	90	0.55 g
Captan 50W	80	0.53 g
Lesan 40W + Terraclor 75W + Agrimycin 21W	100	0.50 g
Benlate 50W + Captan 50W	100	0.50 g
Truban 25E + Benlate 50W + Agrimycin 21W	100	0.45 g
Terraclor 75W	90	0.45 g
Benlate 50W + Captan 50W + Agrimycin 21W	60	0.30 g

* Leaf cuttings were propagated 44 days in a peat:perlite growing medium.
** Root Development Index where 0 = no root development and 5 = maximum root development.

Rooting activity and root development of *Peperomia caperata* 'Blackie' leaf cuttings were significantly influenced by the number and type of chemicals used for sanitation. Poor results obtained wtih once-applied chemical drench treatments such as captan 50W and Terraclor 75W suggest a higher potential

for phytotoxicity on tropical plant species than on woody cuttings such as boxwood. Rooting and root development on peperomia leaves were also reduced by the use of most of the combination drenches used for sanitation during propagation. Only the broad spectrum chemical treatments Subdue 5E + Benlate 50W, and Truban 5G + Benlate 50W + Agrimycin 21W, resulted in greater root development on cuttings and appeared to be well suited for disease protection during propagation of *Peperomia caperata* 'Blackie'.

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SANITATION: A DELIBERATE, ESSENTIAL EXERCISE IN PLANT DISEASE CONTROL

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Growth difficulties of ornamental plants produced within a commercial nursery are usually due to poor management practices. Results of such practices are reductions in plant quality and increases in disease losses. Among these less than desirable conditions for plant production is the lack of a well-conceived disease control program that includes sanitation — a deliberate, essential function for disease control. All comments will be directed toward this end.

A sound sanitation program must be an integral part of all production practices. This becomes apparent when requirements for plant disease development are understood, i.e. (1) the presence of a pathogen; (2) the presence of a particular, susceptible host; and (3) a proper environment. A pathogen is either a fungus, bacteria, virus, mycoplasma-like organism, or nematodes. Any one of these particular disease-causing entities causes a particular disease on a particular plant under certain conditions. The host plant, the one you grow to make money is, of course, present within your facility; the pathogen is either present or soon will be if poor sanitary practices exist. Of equal importance in the disease development scheme is a precise environment, which varies with a particular disease. Some disease-inducing factors common to many foliage and flower diseases are, unfortunately, the same as those which are necessary for plant growth. Temperature extremes, high humidity, high moisture, improper nutrient regimes, improper pH, and limiting light levels, either singly or in combinations, are very important environmental conditions necessary for disease development. For instance, some diseases require free moisture on the foliage during dark periods; this is a disease requirement which can be avoided by keeping the foliage dry during dark hours.

If improper management practices such as poor irrigation practices, improper plant locations, planting or sticking too deeply, use of a poorly drained medium, or poor fertilization methods occur within a nursery production system, poor plant vigor and quality are likely. If sanitation practices are limited under such conditions, disease becomes more prevalent and severe due to the poor health of the plant.

The objective of this presentation is to delve into the particulars of a sanitation program designed for propagation. Success of such a program is dependent upon a firm philosophy that prevails perpetually. Economically successful growers are utilizing a "holistic" philosophy towards plant production — plant health from start to finish — whether they are aware of it or not.

Disease Prevention: All disease control approaches are based on one basic criterion — prevention. Plant disease prevention is essentially a quasi-synonym for proper sanitation practices. Simply, the sanitation philosophy is the "clean kitchen", or a "keep 'em out, not get 'em out", approach.

Implementation of a sound sanitation program just does not happen as we have seen that a disease *just* does not happen. Often some disease-causing organisms make their way into a nursery production cycle because certain safeguards are lacking. In order to avoid the introduction of these organisms into the nursery production cycle, potential sources *must* first be defined by the producer. The most common sources are as follows:

(1) contaminated soil or potting mix splashed onto clean areas by drops of water from irrigation or rain;

(2) pathogens deposited on cuttings when placed in contaminated water or hormone solutions;

(3) hoses dropped carelessly to the ground where pathogens get into the nozzle-end and are expelled into pots or on benches at the next watering;

(4) pathogen-infested soil and organic material not removed from used flats, pots, benches, or other containers prior to disinfection;

(5) contaminated soil carried on tools, covers, or worker's hands;

(6) sterile potting mix placed on contaminated greenhouse floors, benches or flats caused by foot traffic;

(7) flats or plants placed on the ground, and

(8) planting infected seed, cuttings or seedlings.

Because there are so many sources of contamination, emphasis must be placed on practices which keep the pathogens out (exclusion) of the production cycle.

The attitude towards disease control in many nurseries is to (1) "dump a chemical on it", or (2) correct only one specific problem at a time. However, these problems *must* be solved by making changes or adjustments in the entire production cycle. The usual piecemeal approach is not applicable if success is to be achieved.

The efforts of sanitation are probably one of the most important functions in propagation, but the process must be viewed together with other different functions. Think of production as consisting of links in a chain; one broken link can result in losses due to plant disease.

A Simple Sanitation Program For Propagation: As previously described, plant disease development in the nursery is seldom an isolated incidence. Below are some simple, but yet important functions, that can be utilized to minimize disease problems.

A. *Establish Pathogen-Free Stock Plants:* Certain safeguards must be implemented to insure the stock plants remain healthy. Consider the following:

1. Stock plants or mother blocks should be isolated from propagation areas. Avoid weedy and known disease areas.
2. Establish regular spray schedules to control foliage, stem or flower diseases on stock plants. Drench with appropriate soil fungicides as added insurance.
3. Isolate newly introduced plants to determine health status prior to introduction into the existing nursery or greenhouse.

B. *Collection of Cuttings:*

1. Collect cuttings from tops of apparently healthy plants. These are usually free of soil-borne organisms. Some nurseries even grow certain plants on trellises.
2. Avoid root divisions unless absolutely necessary.
3. Break shoots rather than cut with knives or pruning shears. If the latter are used, disinfect frequently with alcohol dips using 70% to 95% grain, rubbing, or wood alcohol. There are other disinfectants available from which you may select, including commercial chlorine bleach at a 9:1 ratio, iodine solutions, phenolic sprays.
4. Place cuttings only into containers or on surfaces that were previously disinfected. Again, chlorine bleach can be used as the disinfectant.
5. Avoid dipping cuttings into aqueous solutions if possible. If this must be done, change solutions and disinfect containers frequently.
6. Prior to sticking, some growers dip or soak cuttings in fungicide dusts or aqueous suspensions. One material frequently used is 10% captan dust or a suspension of 1 lb. captan 80% WP/100 gals. water.

C. *Flats and Pots*

1. All new containers in the propagation area should be so stated to avoid contamination. Contamination in foam-type rooting blocks seems to be bacterial.
2. Containers that are reused should be treated thusly:
   (a) Remove old media adhering to surfaces and disinfect with chlorine, iodine, or another disinfectant. For wooden flats brush or spray a 2% copper naphthenate solution. Wait 2 or 3 weeks before using newly-treated wooden flats.
   (b) *DO NOT* nest or stack containers before disinfection. Thorough coverage of container surfaces will not be achieved.

D. *Propagating Media:*

1. *Never* reuse potting or propagating media, period!
2. Sterilize or pasteurize media if new soil is used. Methyl bromide or heat (dry or moist) are excellent preplant treatments. However, a waiting period before use is required. At present we do not have dry materials for incorporating in the medium, but in the future we probably will. So far, slow-release formulations have not been satisfactory.
3. If mixing your own potting medium, use only disinfected surfaces or properly located concrete slabs.
4. Store properly; avoid foot traffic.
5. If automatic pot fillers are used, be sure all surfaces are clean.

E. *Propagation Area:* Raised benches are superior to ground beds in that they are less prone to contamination, easier to clean and easier to keep clean.

1. All plant debris and potting soil should be removed from structures.
2. Benches should be disinfected with sodium hypochlorite, chlorine bleach, iodine, or other solutions. Treat wooden benches between crops with 2% copper naphthenate to preserve and disinfect them. A two-week waiting period is necessary before plants can be introduced into this area. Although fumigation is a possibility, it can easily miss critical spots and pests. In addition, there is a high risk of phytotoxicity.
3. Avoid unnecessary handling of plants and traffic in houses once they are clean.
4. Be sure all hoses are clean.

5. If root diseases had been a problem with a previous crop, consider disinfecting all irrigation water lines. An iodine solution injected into the system at the rate of 3 oz./gal. of water has proven to be successful for several nurseries.

6. *Do Not Use Untreated Pond Water in Propagation!*

Poorly graded areas surrounding ground beds are easily contaminated by normal water runoff. Ground beds are difficult to keep clean. Pathogens in water droplets are splattered about during irrigation or rain and are easily carried into ground beds from contaminated areas. Even raising the bed the height of a brick helps greatly. Follow these procedures if ground beds are used in propagation:

(1) Thoroughly prepare the soil. Improve drainage. Incorporate fertilizer as needed.

(2) Treat with a wide-spectrum fumigant. See your state extension service for specific information. Always fumigate between crops.

(3) Treat walkways as well as the bed area.

(4) Use boards or cinder blocks to build up bed perimeters to avoid flooding.

F. *Sanitation Practices After Sticking:*

1. Space cuttings to allow for good ventilation.

2. Any plant debris should be removed regularly. Carpenter aprons can be used by personnel to collect debris in pockets during their daily activities. *Covered* garbage cans should be placed at each end of the propagation area.

3. Apply fungicides on a regular basis. One successful schedule is as follows. (Always read the label of the pesticide before use):
   (a) *First week*: Spray captan at the rate of 1.5 lbs/100 gals. water.
   (b) *Second week*: Spray mancozeb (80% WP) plus benomyl (50% WP) at the rate of 1 lb. and ½ lb. per 100 gals. water, respectively.
   (c) *Third week*: Spray chlorothalonil flowable at the rate of 1 pint per 100 gals. water.
   (d) Repeat the above sequences.

4. For added insurance some growers drench with soil fungicide at 4-inch intervals. This is a good idea. Note that drenching is done after cuttings are stuck and in place while soaking is done at the time cuttings are

made. The base, or the entire cutting is put in the solution. In both cases proper worker protection should be provided.

5. Do not be plant molesters.
6. When spot treating dry areas in propagation, use low water pressure for irrigating with hoses.
7. Hose nozzles should be kept away from ground contact at all times.
8. Avoid excessive misting. Adjust misting to compensate for rainy, humid days. Misting at night is unnecessary; allow sufficient time in late afternoon for foliage to dry before nightfall.
9. Remove dropped leaves or cuttings that appear to be dead or declining.
10. Get a proper diagnosis of any growth difficulty so that correct remedies can be applied.
11. The number of people entering propagation areas *should be limited.*

Examine all Plants Regularly: A good grower frequently observes moisture, leaves, and root condition. Diseases detected early are more easily controlled. Diseased plants should be removed from the growing area as soon as possible. The disposal area for such debris should be located well away from the growing areas, storage areas, potting area and water source.

Even under the best management conditions, we sometimes still fail to consider plant needs adequately. You should always know how the plant grows and its optimum growth requirements.

In conclusion, there are so many things that predispose plants to diseases that a grower must use sound management practices that include a precise sanitation program. A grower must constantly develop knowledge about the plants grown. There is no substitute for this knowledge.

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TISSUE CULTURE OF PECAN, OAK, AND OTHER WOODY PLANT SPECIES

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Developing Plant Reproduction International, Inc. and moving from the academic world to industry has been a challenge — a challenge that has increased my respect for all industry-related people. In the industry one must not only keep up with new technology, but one must also be creative, stubborn, a good business person, a leader, and have the mental and physical capacity to prevail. To start and develop a business takes a lot of pioneer spirit with the tenacity to succeed.

At P.R.I., Inc. our main emphasis is on quality and our present objectives are:

1. To produce herbaceous and woody plants through tissue culture. At present all production work is pre-contracted.

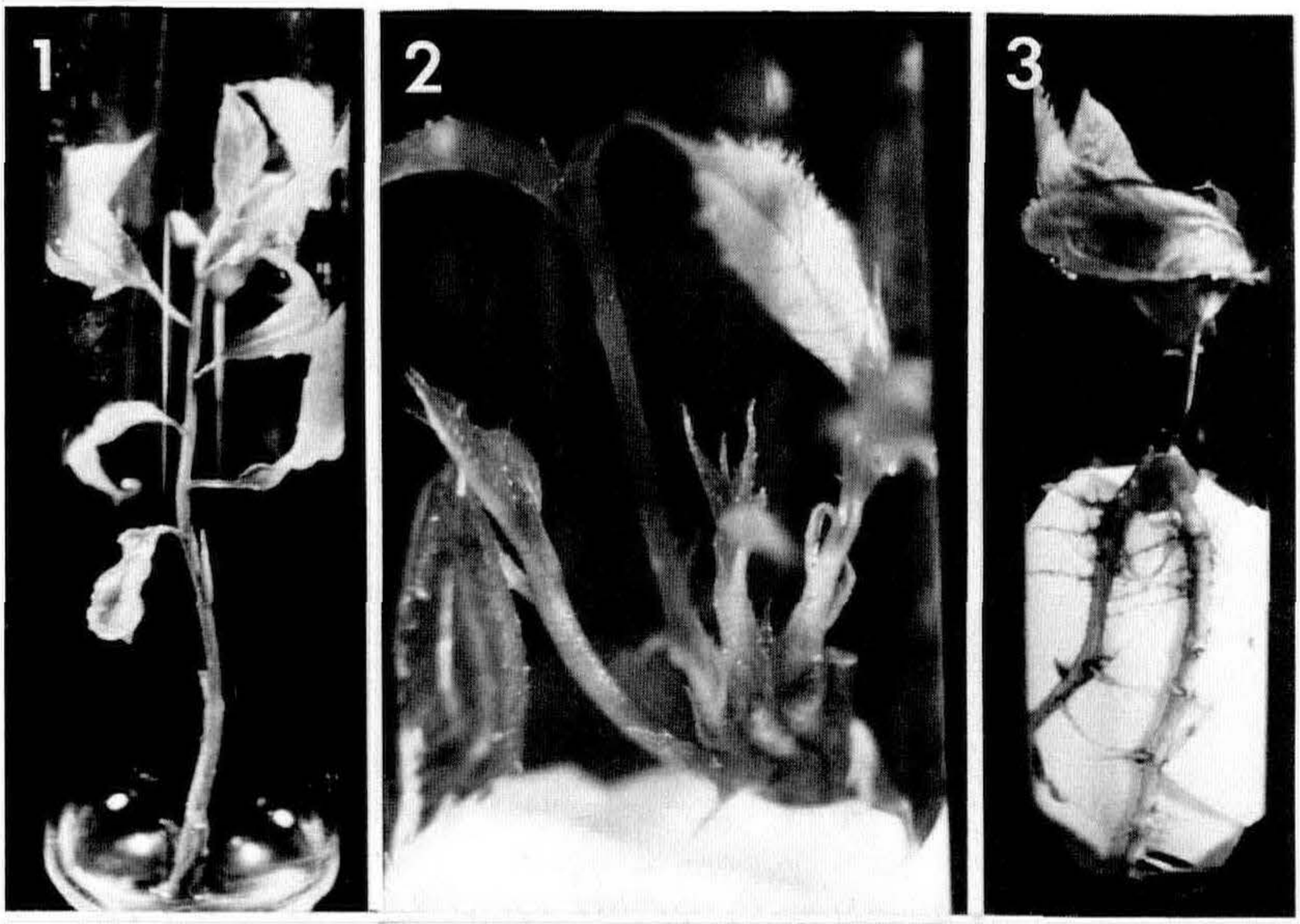
, 2. To research for procedures and better production systems to propagate plants via tissue culture. This research is either contracted or of our own interest.

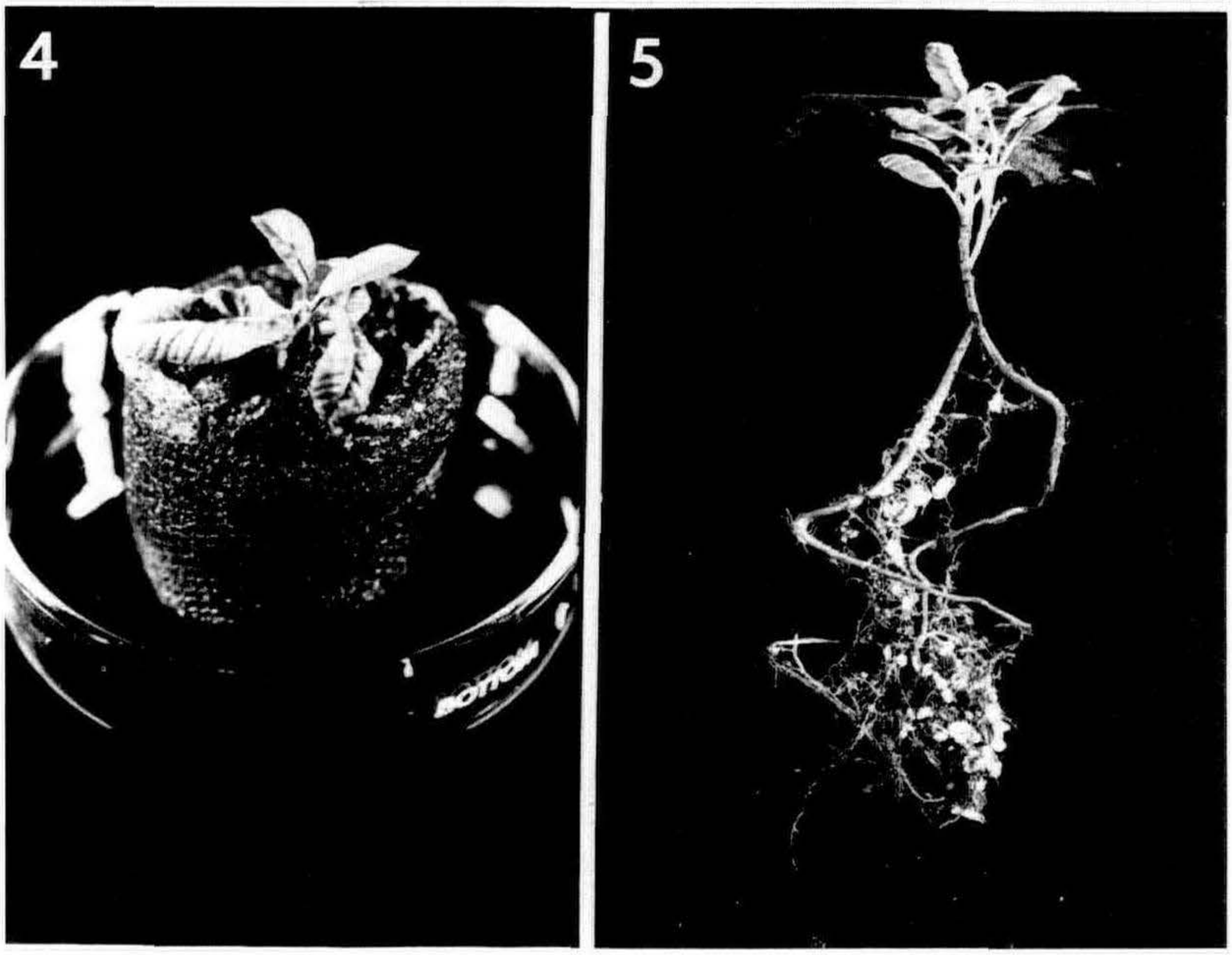
3. To offer consulting services in plant propagation and production, especially in the field of tissue culture.

A field of major concern to us is woody plant tissue culture, because it is in a developmental state and there is much to be accomplished. However, working in the commercial world one finds that it is important to keep a constant production of quality plants to satisfy the industry needs. The development of efficient crop production systems and better quality of stock plants are the most important problems in woody plant tissue culture. To solve these problems only one thing is required — TIME. It takes time to develop new procedures, to increase the number of stock plants in culture and to develop new selections and varieties.

It is for these reasons that we are producing herbaceous ornamentals such as gerbera, syngonium, spathiphyllum, dieffenbachia and ferns, while developing new production techniques for woody plant species.

Two years ago at the 1981 meeting of the Southern Region of the International Plant Propagation Society in Houston, Texas, I presented a complete procedure for tissue culture production of thorny blackberries and preliminary informaton for the *in vitro* shoot multiplication of pecans. Today I would like to





Figures 1-5. Pecan tissue culture. Fig. 1, lateral shoot development. Fig. 2, multiple shoot development. Fig. 3, *In vitro* rooting. Fig. 4, fully acclimated plantlet. Fig. 5, vigorous root system of plantlet.

present the complete procedures for tissue culturing pecans. This work was completed in June, 1982, at Texas A & M University, and will be published in *HortScience* with Keith Hansen as senior author.

A production system for clonal pecan rootstock would be advantageous, since at present all pecan rootstocks are seedlings with great genetic variability (3,4,6). Stem and root cuttings have been used to propagate pecans, but only with root cuttings has limited success been achieved. Major drawbacks are poor rooting and survival after transplanting (1). Another method is mounding. However, the rate of multiplication is limited and seasonal.

Attempts at pecan tissue culture were reported by Smith in 1977 (5) and Knox in 1980 (2). However, neither was successful in obtaining well-rooted explants, and plantlets did not survice transplanting.

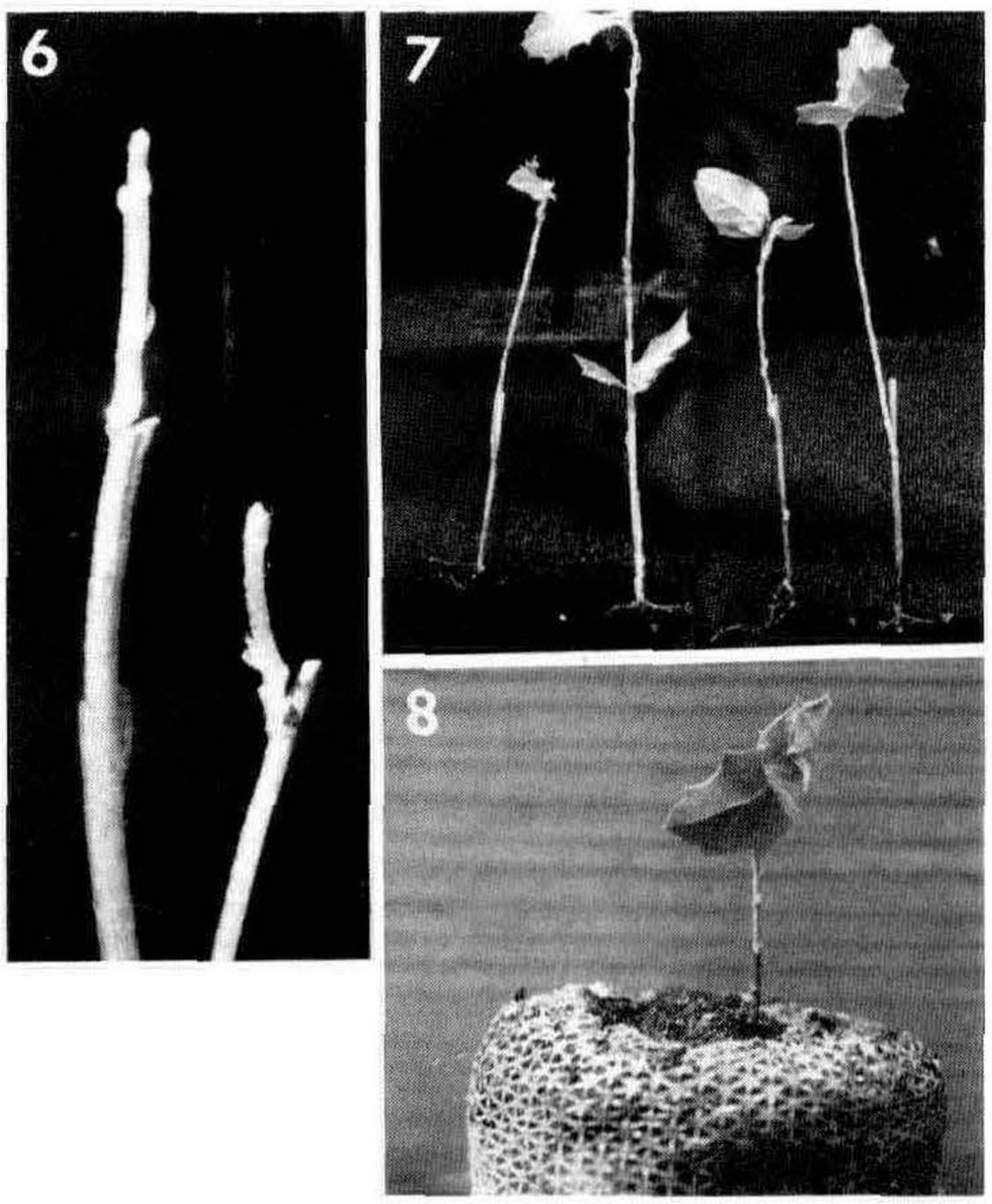
Since we were interested in developing needed procedures for rootstocks, we used explants or plant material from 2-month-old seedlings of the cultivar 'Desirable'. The seedlings were grown under two conditions: 16-hr photoperiod in a greenhouse, and in complete darkness.

Shoot Multiplication. Explants consisted of stem cuttings or nodal cuttings, washed with 1% Liquinox® and sterilized with 0.525% NaOCl for 10 min. Explants were placed in test tubes containing Woody Plant Medium (WPM) modified with 2% glucose. All cultures were placed in darkness for the first 2 weeks and under 16-hr photoperiod for the remainder of the experiment. Best shoot break and multiplication was obtained using 3 mg/liter benzyl amino purine (BA) (Figure 1). Etiolated stock plant explants had better bud break and elongation at the beginning, but after 6 to 8 weeks there was no difference between etiolated and non-etiolated stock plants. It was with 3 mg/liter BA that we obtained more than one shoot per node, and in some cases 10 shoots per node were counted (Figure 2). It is important to remember that 'Desirable' has 4 to 5 buds per node, but normally the most apical or primary is the only one that breaks.

Rooting. Rooting was accomplished *in vitro* in test tubes and *ex vitro* in peat pellets. For *in vitro* rooting, excised *in vitro* developed shoots were placed in test tubes containing WPM plus 2% glucose. Best rooting was observed using 3 mg/liter indolebutyric acid (IBA) for a 10 day dip (Figure 3). For *ex vitro* rooting, *in vitro*-derived shoots were excised and placed in test tubes containing WPM plus 2% glucose and 10 mg/liter IBA for 10 days. Shoots were then transplanted to peat pellets, watered with half-strength WPM minerals and covered with

plastic cups. Fifteen days after insertion, the plastic cups were perforated with two 5 mm holes to begin acclimatization. Two months after initial treatment with IBA, plantlets were well-rooted and fully acclimated to greenhouse conditions, where they grew vigorously (Figure 4). Acclimated plants had functional and vigorous root systems with profuse lateral branching from primary roots (Figure 5).

During the present meeting we have discussed plant species that could be propagated more conveniently with tissue culture. Many of them are difficult to multiply due to a limited number of propagules. Others, such as oaks, can only be propagated from seed, which results in genetic variability. We have been working on procedures to tissue culture live oaks for the last 12 months and recently have had excellent results for shoot break and mutiplication (Figure 6). Preliminary experiments on rooting have been also very encouraging (Figure 7). We have obtained oaks rooted *in vitro* and they were successfully acclimated to greenhouse conditions (Figure 8). This is just preliminary, and we are planning to do final experiments this coming spring. We are also working on Texas pistachio, *Ilex vomitoria*, and *Hibiscus* spp. and also hope to get other new or difficult-to-propagate woody plants in culture. Tissue culture techniques can add greatly to the number of cultivars available to the woody plant industry in the years ahead.



Figures 6 to 8. Preliminary development in live oak tissue culture. Fig. 6, lateral shoot development. Fig. 7, *In vitro* rooting. Fig. 8, fully acclimated plantlet.

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ESTABLISHING TISSUE-CULTURED PLANTS IN SOIL

JOHN L GRIFFIS, JR., GARY HENNEN, AND RAYMOND P. OGLESBY

Oglesby Plant Laboratories, Inc.

Hollywood, Florida 33023

It has been almost 9 years since Oglesby Nursery, Inc. ventured into the plant tissue culture business. In that time, our facility has grown from a small laboratory with one technician and 120 ft^2 of culture space to a modern production laboratory with over 3500 ft^2 of culture space and about 40 employees, plus a separate research and development facility with 250 ft^2 of culture space and 2 employees. The demand for tissue-cultured plants is such that our laboratory is in continuous operation, 24 hours a day, Monday through Friday. An additional shift also operates on Saturday. We have, over the years, successfully propagated through tissue culture more than 400 kinds of plants including bananas, pineapples, plantains, gerbera daisies, spathiphyllums, daylilies, caladiums, and many other ornamental species (2). Included among current research projects are tissue-culture propagation of avocados, nandinas, heliconias, araucarias, various spices, and numerous other plants.

Because of our considerable expertise in tissue culture propagation of plants, we are often asked many questions concerning all stages of the process. One of the most common

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Because of our considerable expertise in tissue culture propagation of plants, we are often asked many questions concerning all stages of the process. One of the most common

questions asked is "How do you successfully establish tissue-cultured plants in soil?"

Since our liner division, which is one of our laboratory's largest customers, successfully establishes thousands of tissue-cultured plants per month in soil, we would like to share with you the factors we consider and the procedures we follow at Oglesby Nursery, Inc. to accomplish this task.

For those of you not completely familiar with tissue culture propagation systems, there are 4 steps or stages involved in the process. Stage I involves selection of plant materials to be cultured, disinfestation of the plant tissues, and establishment in the tissue culture medium. Stage II basically involves the multiplication of the plants. Stage III involves the rooting of the plantlets from Stage II. Stage IV involves the return of the rooted plantlets from Stage III to the soil and the natural environment. All plant tissue culture systems require Stages I, II, and IV. Some plants require Stage III while others may be returned to the environment, i.e. Stage IV, directly from Stage II and are treated as unrooted microcuttings (1). Many factors are involved in successfully returning tissue-cultured plants to the environment.

The single most important factor affecting plantlet establishment is plant quality. Whether the plantlets are Stage II microcuttings or Stage III rooted plantlets, plantlet health is very important. Some factors which influence plant health include light availability, media components, and bacterial or fungal contaminations. We know that low light intensity will produce weak, spindly plantlets, but high light intensity may produce burned, chlorotic foliage. The ideal amount of light varies with the plant species involved; however, at Oglesby we generally use 200 to 300 f.c. for Stage II cultures and 350 to 600 f.c. for Stage III culture areas. Although all media components may have some affect on the tissue-cultured plantlets, we have found that selection of cytokinin used in Stage II greatly affects the survivability of plantlets in Stage IV. The use of benzyladenine in Stage II reduces the number of plantlets of liriope, schefflera, or philodendron that survive transplanting to as low as 10%. The use of kinetin or 2iP instead of BA gives us a survival rate in excess of 90%. The reason for this is not yet clear, although it appears that BA has some adverse effects on stomatal regulation. Other plants, however, are not adversely affected by BA. Additionally, plantlets which become contaminated during Stage II or III may also show some loss of transplant survivability. These three factors are all dealt with in the laboratory and are out of the purchaser's control. However, there are many factors which you, as a

purchaser of Stage II microcuttings, or Stage III rooted plantlets, do control.

Factors in Stage IV which may directly affect transplant survivability of tissue-cultured plantlets include soil mix selection, pot selection, humidity control, watering techniques, light availability, and pesticide application.

Although there are several important factors involved in soil mix selection, the main requirement is that the mix must be pasteurized or sanitized. Drainage is also an important factor, as is the addition of fertilizer to the mix. Other components that may be added to the soil mix include perlite, vermiculite, polystyrene, bark, sand, and peat. The mix must provide adequate aeration yet also hold enough moisture to stimulate root development. As an example, we use Metromix 300, supplemented with Osmocote 13:13:13, Micromax, and additional perlite for drainage and aeration for the transplanting of gerbera daisies and spathiphyllum out of Stage III.

Selection of the correct pot or tray size may also affect survivability of tissue-cultured plantlets (not to mention your labor and costs). Again, the main requirement here is cleanliness. The pots or trays should either be new or sanitized if previously used. The size of the cells or pots varies with the space requirements and the ease of handling required. There are a large variety of trays and systems available such as cell packs, peat pellets or cubes, Todd Planters, single pots, and larger cell trays. At Oglesby spathiphyllum and gerbera daisies are planted in Grow System 73 cell trays with 1¼-in. cells. These plants can grow in such cells for 2 to 3 months before they are shipped as liners or potted up into larger containers. Bananas, on the other hand, are sometimes planted directly into 4-in. cells where they attain a height of about 1 ft. in 2 to 3 months and are then directly planted into the field. We are also currently investigating the use of newer systems that may make better use of available space, such as the Castle & Cook trays, which hold 400 plantlets in an area only slightly larger than 1 ft^2.

Another very important factor in transplant survivability of Stage II microcuttings or Stage III rooted plantlets is humidity and moisture control. Since the plantlets are coming from an environment that provided them with 100% humidity, they need to be given a similar environment and gradually hardened-off. We generally transfer the plantlets into trays, water them in, and place them in one of several structures that help us maintain a high-humidity environment. These various structures all have advantages and disadvantages, as listed below:

STRUCTURE	ADVANTAGE	DISADVANTAGE
1. Humidity tent (clear or shaded plastic enclosure with or without mist system).	Relatively inexpensive; Relatively easy to construct; Does excellent job of maintaining high humidity.	Heat build up; may be difficult to control temperature; Must be monitored often for misting or watering; "Permanent" structure required.
2. Automatic mist system (with or without plastic coverings).	Automatically mists plantlets and increases humidity, therefore requires very little labor to monitor; Variable controls allow variation in amount of mist and timing of mist (e.g. 5 seconds every 10 min. to 3 min. every 4 hours).	Leaches nutrients from soil and plantlets; Soil may be too wet; System may result in serious fungal or algal buildup — should be cleaned often; "Permanent" structure required.
3. Plastic covers (covers single tray)	Allows greater flexibility with different crops since each tray is maintained separately; Does excellent job of maintaining high humidity; Does not require any structural changes to existing facilities; Quick and easy to use, portable system.	Heat build up can be very rapid since air space provided is small; Requires a great deal of labor to examine each individual tray several times a day.
4. Fog systems (high pressure systems).	Maintains 100% humidity automatically; Does not leach soil or plant nutrients; Lowers heat buildup significantly; Provides pleasant conditions for labor force to work in; May also help lower light intensities.	Very expensive; "Permanent" structure required; High maintenance requirement if water is not very pure.

With any system used, the plantlets will require the highest possible humidity levels in the beginning and a gradual reduction in humidity over 1 to 4 weeks as the plantlets become established. Some of these systems lend themselves better than others to this gradual hardening-off process.

Other important factors involved in survivability of tissue-cultured plantlets include light intensity and pesticide application. Plantlets must be protected from high light intensity

since they are coming from a low-light environment. The available light should be gradually increased as the plantlets become established. Our greenhouse fog system has 90% shade. After about 2 to 4 weeks in this structure plantlets are moved to other greenhouses with 73% to 80% shade. Some plants, such as spathiphyllum, will remain at 73% shade until they are sold. Other plants, such as gerbera daisies, will be transferred to structures with 30% shade after several weeks at 73% shade. We discourage application of any pesticide during the first 2 weeks after transplanting. Strict adherence to correct sanitation procedures is much more desirable. However, plantlets should be monitored closely after transplanting from the sterile tissue-culture environment and pesticides may be used cautiously if any problems do arise. Be sure a pest is involved before you use chemicals.

As you can see, numerous factors are involved in establishing tissue-cultured plantlets in soil. By paying close attention to them, one should have few problems in establishing tissue-cultured plantlets and in producing an outstanding crop.

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ASEXUAL *MAGNOLIA GRANDIFLORA* PROPAGATION AT SHADY GROVE NURSERY

WILLIAM M. BRAILSFORD

Shady Grove Plantation and Nursery, Inc.
3030 Charleston Road, SW
Orangeburg, South Carolina 29115

Our nursery was established in 1939 by John F. Brailsford, Sr., with retail sales, container yard, and a garden shop in town. Shady Grove Nursery now has 350 acres under cultivation with 150 acres of new ground; 60 acres of this will come into production this year, 25 to 30 acres a year later. Hopefully, we will then be able to rotate fields in the old nursery and top out at 500 acres. We are wholesale growers, now serving landscape contractors, architects, and other nurseries.

Around 20 years ago we realized people deserved better than seedling-grown magnolias. We were also interested in

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Around 20 years ago we realized people deserved better than seedling-grown magnolias. We were also interested in

broadening the usefulness of *Magnolia grandiflora* by selecting clones with different architectural shapes and textures. Consequently, through the years we have developed six *Magnolia grandiflora* selections with distinctly different architectural characteristics. The names of the selections are 'Claudia Wannamaker', 'Margaret Davis', 'Hasse', 'Shade Grove #4', '#5', and '#6'. All of them have dark, glossy green foliage with brown pubescent backs.

We use the same propagation techniques for all six except for the timing of taking the cutting wood. For example, the Hasse #4, #5, and #6 wood was mature and cuttings were taken on June 29 and 30 this year. Claudia Wannamaker and Margaret Davis wood was ready July 5 and 6. In years past the cutting wood has matured much later.

In the actual process of taking the cutting wood, *timing* and *sanitation* are my main two concerns. We take our cutting wood early in the morning while it is still turgid. The wood is placed either in damp burlap or damp vermiculite bags to protect and keep it fresh. While most of the crew is taking the wood, two people are left behind to fill metal flats that have been sanitized with a solution of Clorox and water. They are filled with straight vermiculite. That is right. Straight vermiculite is our propagating medium. It is thoroughly wet down and each flat is tapped down tight to secure the cutting as they are stuck. We used wooden flats for a long time until we found that root rot fungi over-wintered in the cells or pores of the wood. We then changed to metal flats, which we sterilize with a solution of 2 gal. Clorox to 55 gal. water. We can get 4 flats to a wheelbarrow with a rack across the top. As soon as we have 4 flats ready, we soak the cuttings down and go to our open-frame intermittent mist houses. We have a 24 hr. clock to cut on and off, and 10 min. clocks that are set for 2 sec. every 3⅓ min. When we first put the magnolia cuttings in the mist frames, the clocks run from 8 a.m. until dark. As the cuttings begin to callus and root, the watering time is cut back gradually at each stage of the process.

We dip our cuttings in captan, 16 tbs/3 gal. water. We use this for 3 or 4 days until the solution becomes diluted. Other fungicides should work as well. My rooting hormone in the past has been Rootone F, which contains a fungicide. I cut a 45° angle through the bottom of a node, dip the cutting of the fungicide solution, shake dry, and dip it in the Rootone F. Cuttings are inserted in the vermiculite-filled flats 2 in. deep. The cutting's overall length is 4½ to 6 in. depending on the length of the first cycle of growth.

This past summer I did an experiment with different hormones. Rootone F as a powder, Hormodin #2 as a powder, Dip 'N Grow as a liquid at the rate of 1:10, Chloromone as a liquid at the rate of 1:2 with water. Cuttings dipped in Dip 'N Grow rooted fastest, but more rooted and at a more uniform rate using my old stand-by, Rootone F.

Once the cuttings are stuck, we spray on a 2-wk. interval across the top with a fungicide. Once the cuttings start to callus and root, we spray with Sol-U-Grow, a 12-48-8 soluble powdered fertilizer at 4 to 6-wk. interval. If everything goes well, cuttings start rooting in 6 to 8 wks. They are then potted off in 1-qt. and 3-qt. pots, depending on the quantity and density of the root ball. The one draw-back to straight vermiculite is that the roots are very tender and have to be handled with extreme care. In general, we have found these techniques to be quite successful in our particular production scheme.

Rootone F - A combination of NAA, IBA and thiram.
Hormodin #2 - 3000 ppm IBA
Dip 'N Grow - 10,000 ppm IBA + 5000 ppm NAA
Chloromone - Alfalfa extract plus NAA

PROPAGATION OF DWARF NANDINA CULTIVARS

TIM GWALTNEY
Flowerwood Nursery, Inc.
Route 1, Box 130
Mobile, Alabama 36605

Flowerwood Nursery is currently producing two dwarf nandina cultivars. They are:

1. *Nandina domestica* 'Purpurea' (*N. domestica* 'Nana Purpurea')

2. *Nandina domestica* 'Harbour Dwarf'

We began producing 'Nana Purpurea' by cuttings in 1978 from our first batch of purchased plants. 'Harbour Dwarf' was started from purchased plants in 1980.

Dwarf nandina cultivars are high-value crops that are relatively easy to propagate if correct conditions can be met and if a large supply of stock plants are available. This latter factor accounts for the difficulty of getting large production numbers in a fairly short time. Generally, on a young plant only one or two cuttings are available at any one time, with the 'Harbour Dwarf' at this stage producing the fewest cuttings.

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As the stock plants become older and cuttings are made repeatedly, the number of breaks per plant greatly increase. At this time cutting availability allows one to multiply production greatly.

The largest number of cuttings are usually available on 'Purpurea' as opposed to the 'Harbour Dwarf'; but if division is used as a means of propagation, 'Harbour Dwarf', after a few years, produces a vast number of suckers that can be separated from the parent plant and potted up already rooted.

In the propagation of dwarf nandina cultivars we will consider separately the two cultivars grown at Flowerwood Nursery.

First, *Nandina domestica* 'Nana Purpurea', (often called "Dwarf") will be discussed. This cultivar is propagated by tip cuttings. The season in which these are taken is variable. Cuttings are taken from outdoor plants either in late spring, summer, or early to mid-fall. If the parent plant has been overwintered in a protective structure, cuttings can be taken anytime and good results are obtained. Once the cool weather has hardened off the tops or a frost has fallen on the plants, the cuttings seem more difficult to root. This hardening is noticeable by the overall reddish coloration of the foliage and the darkening of the stem.

Cuttings are generally collected in the early morning while the plants are fresh and turgid. These are kept in a damp burlap sack. If collection is later in the day and the temperature is very warm, the cuttings are put in a large plastic garbage can with water in the bottom one-third to keep the cuttings moist.

The type of wood looked for in taking cuttings is current season's wood that has stiffened. The ideal cutting wood has a pinkish color, and is 1½ to 2½ in. long. The cut is generally made just above the point where the wood turns to a brown color. As much foliage as possible is left on the cuttings. Foliage color should show a lot of green, as an overall red color to the leaves generally indicates wood that is too hard.

Cuttings are gathered from the cutters frequently and taken to the stripping shed. They are then dipped in a fungicide for 10 to 15 min. We use captan 50% wettable powder at a rate of 2 lb/100 gal. of water.

After all the cuttings are gathered and taken to the stripping shed they are prepared for sticking in the rooting mix. No foliage is stripped away. It is our belief that a maximum amount of foliage left on the cutting enhances rooting. The

stems are cut to remove any brown wood that may have come with the cutting and the finished size is 1½ to 2½ in. of stem length.

The stems are then dipped in an IBA solution for 3 sec. If the wood is very soft, we use a rate of 1,250 ppm IBA. If the wood is a bit stiffer, 1,870 ppm is used.

The cuttings are now ready for sticking. They are put into round pint pots or 4-in. square pots in trays placed on the ground beds. This size is used to give more space to the heavily-foliaged cuttings and to reduce the risk of fungus attack.

The rooting mix consists of:

3 parts aged fine pine bark
2 parts Canadian peat moss
3 parts perlite

For each cubic yard of this mix we add:

3 lb. Osmocote (18-6-12)
1 lb. Micromax minor elements
5 lb. dolomite

All cuttings are stuck to a minimum depth, just enough to hold them up on the pot, about ½ to ¾ in. deep.

The cuttings are then put under intermittent mist. The greenhouse is covered with 51% shade cloth and a 3-ft. wide black plastic on the side to block excess wind and damaging light. The mist is controlled by an Intermatic cycler using a 60-min. clock with a time-delay to regulate the duration of the cycle. The sprinklers are Ross 24 in a single line set 14 ft. apart.

Generally, the cuttings are started on a 15-min. cycle; if it is hot during the day, the clocks are changed to a 10-min. cycle at mid-day. They are reset back to 15 min. late in the afternoon. This amount of water helps minimize shock, and after a few days the cycles are reduced. We then begin them on a 30-min. cycle and set them up to 15 min. in the middle of the day. Rarely is a 10-min. cycle used, but it may be still necessary during the heat of the day. Later in the afternoon the cycles are reduced, and we finish on 30 min. until the clocks go off for the night. By the end of the second or third week only a 30-min. cycle is needed as roots begin to appear. Reducing the water as much as possible helps to keep down fungus. Also at this time the on-off cycle of the 24-hr. clock is reduced. Generally the clocks can be cut off entirely by the fourth to fifth week as most cuttings will have rooted.

The previous paragraph describes warm-season rooting, but many of our cuttings are also rooted in the fall and winter.

In mid- to late-fall our rooting houses are covered with poly and ventilated on both ends. During this time the automatic cyclers are used on a maximum spacing between mist or are operated manually. The exact settings are dictated by the heat of the house during the day, how much water is retained on the foliage, and how quickly it cools in the afternoon.

By late fall and early winter, if good cuttings are available, they are stuck in completely enclosed houses. All the mist is hand controlled, either with hand-operated sprinklers, or by building up humidity with a water hose. In this method humidity is built up in the morning by wetting the walks and walls. This, and a periodic light mist, will hold the plants all day.

As many people can attest, high humidity rooting is very efficient, yet the chances of disease are magnified and must be monitored frequently.

All of our propagating houses are sprayed regularly in the afternoon after the clocks go off. We alternate between captan and Benlate[1] weekly. After the plants root, we also use Daconil[2].

High-humidity houses root cuttings quickly. If it is not too cold during the rooting cycle, they generally can be rooted in 4 to 6 weeks.

After our liners root, we supplement them with Sta-Green (12-6-6) at a rate of 1 lb./100 ft.^{2}. This is applied every 2 to 3 weeks in the spring and summer, then less frequently in the fall. No fertilizer is applied in the winter after one initial fertilizing.

The second cultivar that is propagated is the *Nandina domestica* 'Harbour Dwarf'. This is done either by tip cuttings or by division of suckers.

Tip cuttings are treated in much the same way as the *N. domestica* 'Purpurea'. The stems are similar in maturity but are usually more green in color. The stem diameter is larger and not as long, maybe ¾ to 1½ in.

The cuttings are kept moist and cool by keeping them in wet burlap sacks or in a water-filled plastic garbage can.

The whole process of cutting and collection is similar to the "dwarf" except that the diameter of the foliage is reduced on the cutting bench; the number of leaves is not reduced. The leaves are cut down to where the cutting is about 5 inches across. We feel that this cultivar is extremely sensitive to

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[1] Benlate - benomyl
[2] Daconil - chlorothalonil

drying so we are very careful to keep the cuttings moist. Once they are stuck in the propagation mix, we are careful not to let them go dry, even for a short while during the day.

During the warm season the clocks are started out on a 15-min. cycle in the morning and then moved up to a 10-min. cycle by midmorning, until late afternoon when it is cut back to 15 min. After about 1 wk. we start the cycle out on 30 min., but go to 15 min. by midmorning and to 10 min. by midday. It is important to keep moisture on these leaves because the 'Harbour Dwarf' stresses more easily than 'Nana Purpurea'. In the afternoon the cycle is cut back to 15 min., then later to 30 min. until the mist goes off for the night.

Winter rooting of 'Harbour Dwarf' is by high humidity under poly, using the same process as with the 'Nana Purpurea'.

The other method that is used to produce 'Harbour Dwarf' is by division of suckers. Our stock plants are in 4-gal. containers. After several years the containers become full of suckers, which line the outside of the root ball around the rim of the can. The suckers are separated from the parent plants and kept moist by storing them in a plastic garbage can filled one-third with water. These are then taken to the stripping shed for preparation. Here the rooted suckers are divided into individual plants. Each plant has at least 1 or 2 green leaves. After all the suckers have been divided, they are potted into pint pots and set inside a plastic house. The potting mix is our standard propagation mix of 3 bark, 2 peat, 3 perlite, plus additives mentioned earlier. These plants are then treated as cuttings for about 10 to 14 days by misting them once an hour from midmorning to midafternoon.

After the plants no longer need to be misted, they are fed with supplemental fertilizer. Sta-Green (12-6-6) at the rate of 1 lb./100 $ft.^2$ is broadcast every 2 to 3 weeks until adequate growth is achieved.

These young plants make a plantable liner in a very short time, as soon as the root ball will hold together once the pot is removed.

In conclusion, dwarf nandina cultivars can be produced readily by following proper procedures. They are very popular in the retail market and command an excellent price for the wholesale nurseryman. They are definitely plants to consider in your production.

QUESTION BOX

The Southern Region Question Box was moderated by Tom Couturier.

FRED GARRETT: We have heard recommendations of from 8 to 15 lbs lime/yd^3 for a 3:1 bark:sand mix. This is certainly a wide range. What crops are we growing?

BRYSON JAMES: Carl Whitcomb says pH is not important as long as we have the correct Ca and Mg levels. It is more important in the field as field soil contains aluminum that can be toxic in very acid soils. The 8 to 20-lb range is all right for all but the ericaceaous plants. Two other factors that affect the rate are the quality of the lime and the quality of the water supply. We often do not identify either. The only way to know is keep records of growth and growth responses, then monitor with soil and tissue analysis.

CARL WHITCOMB: Our water contains 40 ppm Ca. During a 6-month growing season we add 110 in. water per 6-in. container. This gives an excess of 10 times the amount of Ca that would be provided if we put in 8 lb of lime. It would be necessary to add 20 ppm Mg to compensate for the amount provided in dolomite lime. Earlier tests we made showed no damage when lime was omitted simply because we failed to consider water quality. Geranium and gardenia performed best when lime was not added. A 1½:1, or 2:1, ratio of Ca:Mg is best. An imbalance usually shows up as a slight yellowing of older leaves, which then drop. This appears to be normal, making it easy to overlook this deficiency. Podocarpus and pittosporum show yellowing leaf margins with excess Ca to Mg. The Mg atom is always surrounded by water and doesn't attach to the mix as well as Ca. Adding dolomite further complicates the situation since Mg is much more soluble than Ca and the plant experiences a much different ratio than might be indicated by soil analysis. The particle size of the lime will definitely affect its solubility. The temperature in the container can dramatically change plant response to Ca and Mg imbalance.

GARY COBB: We looked at 9 species going from 0 to 10 lb/yd^3. We found no difference in pH, but we did get a response to an increased rate on boxwood. I agree that the Ca:Mg ratio is much more important than pH. We had both juniper and azalea do well using a 6-lb rate. In the end other cultural factors are more important in producing quality plants.

BOB BOCK: Do we have or could we develop standards with which to compare tissue analyses?

BRYSON JAMES: About the best we can do is try to relate to good and bad plants, then compare the two test results. The range is so vast I would not attempt to write down a figure and say this is it.

JUDSON GERMANY: Is there any new development on a way to determine when to water?

GERALD SMITH: There is no way to tell a person when to water. Successful nurserymen knock out a few plants and look. Overwatering is usually a result of frequency and not total amount applied.

CHARLES PARKERSON: When it is hot, junipers seem to shut down so we can easily overwater.

GERALD SMITH: I certainly believe that I have seen over-compensating.

FRED MAY: Does the plant quit taking up water?

GERALD SMITH: It seems to slow down.

GARY COBB: We compared ½ in. of water with syringing 1 hr at mid-day using 1½ min total watering time to give a total of ¼ inch of water. Syringing gave better results.

JOHN MACHEN: Dennis, how do you root crape myrtle in gallons using hardwood cuttings?

DENNIS McCLOSKEY: We use a 90:10 bark:sand mix with 5 lb dolomite and 5 lb Micromax per cu. yd. We put three 3½ to 4-in. cuttings to the can. We do not use hormones and get 95% take. When we take the cuttings depends on the weather. Usually if we wait much past February, the wood is no longer dormant and take is poor.

JOHN MACHEN: What temperature do you think would be needed to harden the wood?

DENNIS McCLOSKEY: Probably 10 days with lows of 26° to 28°F.

STEVE HAMMOND: What is the best time to take cuttings of red-tipped photinia?

DENNIS McCLOSKEY: We are taking cuttings in late September or early October. We would like to take them in April and May but just cannot get it done. We are presently testing 5 concentrations of hormones. The formulations include Hormodin and Dip N' Grow.

JIM BERRY: We use 10,000 ppm IBA for photinia.

FRED MORRISON: What has been your experience with potting machines?

DENNIS McCLOSKEY: I think personally they are fine for greenhouse operations using a less-abrasive soil mix than most nurseries use. We had three but found they were high-maintenance items. The best we could do was 10,000/day/machine, using 10 to 12 people. We can do about 70,000 by hand. With the potting machine the total labor cost for filling, potting, and placing the plants was 4.4¢. When we do this by hand, total labor cost, as close as we can calculate, is 2.75¢.

JOHN HOPKINS: I would like to know how patented or trademarked material can be propagated and sold; that is, how are royalties paid and what are the restrictions?

JIM BERRY: We grow only one. With this particular plant, we have the right to propagate but not sell without the patent tag on each plant. We have some to market that have the tag on them. These we do not have the right to propagate without the patent holder's permission.

JOHN HOPKINS: How can we get a list of patented plants?

TOM COUTURIER: The American Association of Nurserymen, Washington, D.C., or the U.S. National Arboretum, Washington, D.C. should have this.

DICK HENLEY: A trademark has unlimited life but a patent expires in 17 years.

KERMIT MORRIS: We have had no problems with the legalities of using patented material. However, royalties can be high.

BOB BOCK: We have had trouble with some of our 2- and 3-gal azaleas. The stems get very brittle just below the surface and break off.

JIM BERRY: We have looked at cross-sections and believe that a pathogen is involved. The plant was probably inoculated early in the production cycle.

PETER VAN DER GEISSEN: *Cylindrocladium* could have been present in the stock plant.

DAVE SMITH: We are sticking shallow. The plants with this problem seem to have roots only at the top.

GARY TAYLOR: We have had the same problem but did not notice that roots were affected.

CHARLES PARKERSON: We stick in April, using several cuttings per container. We usually do not treat with hormone but may try. We put the cuttings in an unheated house and get rooting in the early summer.

TED GOREAU: What about the technique of holding cuttings in storage before sticking?

CHARLES PARKERSON: We have not had uniform rooting, possibly because we held cuttings too long.

GARY TAYLOR: We take cuttings from our stock plants in March.