you can see that this organization hasn't been standing still the last 17 years. This is the 17th annual meeting. We owe Don a vote of thanks for the amount of work that he has put into this program. I am sure he has found the job of being Program Chairman to be a terrific amount of work.

REFORESTATION WITH VEGETATIVELY PROPAGATED TREES

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The traditional uses of forests have been as watershed protection, as habitat for game and other wildlife, for firewood, for lumber, and for that special spiritual renewal that many people find in the presence of trees. As the human population continues to require more resources, some of these traditional forest uses are being increased and we have returned to others, sometimes in non-traditional ways. For instance, wood alcohol may replace cordwood as transportable energy, and generators fueled by wood waste already feed electricity into our transmission lines. Plywood, laminated and end-glued products from tennis rackets to stadium beams, chipboards, particle boards, and fiberboards, have joined traditional sawn boards and timbers in many old and new uses. The demand for paper and paper products continues to increase and expand. And wood chemists can create plastics from dissolving pulps, food flavors from terpenes, and perhaps soon, food itself from enzymatically degraded cellulose. In short, our forests are taking on renewed importance. In the United States, the recent Humphrey-Rarick bill seeks to ensure that they receive appropriate attention. Foresters are attempting to find more effective techniques for managing the forest resource. The genetic leverage available with vegetative propagation makes reforestation using rooted cuttings one such attractive new management technique, and it appears that its time may now have come.

Some Problems and Features of Forest Regeneration — When one considers the likely costs of site preparation, of planting the trees, of release from competing vegetation, of protection from animal damage, of applying pesticides and fertilizers, of thinning, of pruning, of fire protection, of land-rent charges and taxes, and other costs which must be borne in order to establish a new forest (or even if establishment fails),

then the costs of the planting stock are generally seen to be only a small fraction of the total investment necessary. In such a situation, a proportionally large increase in the costs of planting stock can be justified, even if it results in only a relatively small proportional increase in the value of the established forest.

For many of our forest species, seed crops in the wild do not occur every year, and many of the best-growing and best-formed trees have few seeds even in good seed years. Logging is responsive to market demand for wood, and it is difficult to forecast which year a particular stand will be cut and thus need seedlings for reforestation. Disasters such as windthrow and large fires are much more difficult to anticipate. The history of forest planting contains many examples of poor planting practices as a result of these uncertainties. For instance, seedlings from short heavy-limbed parent trees, or seedlings from trees which evolved under conditions significantly different from those of the planting site, have frequently been used because seedlings from good parents of appropriate origin were not available.

Classical tree improvement for forestry purposes has used selected trees gathered together in seed orchards to get the selected genes back into the forest in higher frequencies. The most common way to create a seed orchard is to graft scions from outstanding selected trees, replicating each clone many times to achieve a large production of seeds. In some of our species, graft incompatibilities have caused widespread mortality in the seed orchards. In some of our species, it appears that many of the very best-growing trees produce few seeds in the seed orchards. On the other hand, including genotypes in the seed orchards that are unusually prolific pollen and seed producers may reduce growth in the forest. The principle in both cases is that photosynthate devoted to sex is usually at the expense of wood production, and there is some evidence that sexiness is heritable in trees.

The question of maintaining diversity in our forests has been much discussed. The weight of current opinion is that monocultures, and particularly genetically-uniform monocultures, should be avoided. The main concern is that the majority of trees in a stand could thus be susceptible to a single biotic or physical event.

Most temperate-forest trees are outcrossing, which contributes to the maintenance of the internal diversity that typifies our native species in forest stands. With an outcrossing mating system, much of this genetic diversity occurs within families. The seed-orchard approach captures only the average performance of its families, but cannot take effective advantage of the

outstanding individual genotypes that occur among the offspring within its families. Furthermore, most outcrossing species are sensitive to inbreeding, and thus mating between relatives should be avoided. This argues against the use of seedlings from selected families in seed orchards as a solution to the graft-incompatibility problem, because crosses between sibling seedlings can result in serious inbreeding. (Grafts are more acceptable with respect to inbreeding, because the inbreeding depression of selfs in most forest trees is so severe that few produce acceptable seedlings. Thus, the quality of orchard-origin seedlings after culling is little affected by crossing with clones.)

Seed orchards are expensive. This leads to a tendency to concentrate on only the most important species in each forest region. Thus, secondary species may be given little or no genetic attention, and may even not be included in forest plantings. There is also a tendency to make seed orchards large, for economic efficiency. The offspring of such large seed orchards will be used over extensive and perhaps ecologically diverse areas. Most seed orchards employ open-pollination. Therefore, they should be isolated from external sources of pollen, such as native and planted forests, and other seed orchards of the same species whose trees are selected from different regions or for different purposes.

Most of the problems outlined in this section are effectively solved by reforesting with selected vegetative propagules.

Arguments for Vegetative Propagation — A cutting orchard, made up of small trees kept trimmed as hedges, can supply propagating material on relatively short notice. New genotypes can be added in years when seed is produced on selected parent trees, and they will be available as cutting donors in years that seed is in short supply.

Large seed orchards can be replaced with small genetically diverse breeding orchards, whose primary function is the production of modest numbers of pedigreed seedlings for inclusion in the cutting orchard. Genotypes which devote little energy to sex can be encouraged to produce the necessary modest numbers of offspring.

Diversity in production forests can be maintained by mixing clones. Selected clones of secondary species can be included in the mix. As the performance of individual clones becomes known, these mixtures can be prescribed so that neighboring clones make complementary rather than competitive demands on the site.

As information on individual clonal performances accumulates, below-average members of families can be rogued out of

the cutting orchard, and the very best can be expanded by adding additional hedges of those genotypes. If the families are open-pollinated and include a mixture of inbred and outcrossed seedlings, it will be mostly the outcrossed genotypes that are selected for extensive use in production forests. Such within-family selection is simply not available in the classical seed-orchard approach to forest management.

An entire region need not be served by exactly the same set of clones. Instead, the forester may order particular clones of some species for one site, and different combinations of species and clones for other sites . . . or even for differing subsites within a planting area. Thus, no two areas need be reforested with exactly the same combinations of genotypes.

Particular ecological conditions not extensive enough to warrant a separate seed orchard can contribute seedlings from their trees to the cutting orchard, and thus can be better served by it.

Disease considerations may still make it advisable to locate the cutting orchard away from forests. But cutting donors of the same species from very different ecological conditions may be maintained near each other, as they will not exchange genes.

Problems Remaining with Most Species — For many of our conifer species, we have not yet learned to root cuttings effectively or economically. In some, rooting percentages are still low. In others, most cuttings root, but they do so a few at a time, so that nursery management of the propagules is difficult. Ideally, we would like 90% or more of the cuttings to have rooted two or three months after being set, and to root within a period of two or three weeks. We need to find media that are appropriate for both rooting and subsequent growth of the cuttings, particularly if containers are used.

A major problem of both theoretical and practical importance is that of maturation. As maturation proceeds, not only does rooting become much more difficult, but the growth of those cuttings that do root generally differs significantly from the growth of the same clones which were rooted in a juvenile condition. The changes that occur with maturation of forest-tree clones are generally detrimental, particularly with respect to volume growth rate. Thus, it is futile to identify good clones if the clones have matured during the test period.

Our nursery people have learned to produce good seedlings of many of our important species. But rooted cuttings are not seedlings, and many of our nursery protocols may need modification or radical change to produce satisfactory rooted cuttings ready for outplanting. It seems likely that root systems will need particular attention.

It also seems likely that rooting percentages, the timing of the rooting event, and the quality of the plants produced, will be improved (perhaps slowly and erratically) as experience is gained with each species. The question of juvenility, however, needs less-conventional approaches. Two general strategies are available: arresting of maturation at appropriate stages; and rejuvenation of mature clones. Interestingly, the repeated hedging used to keep plants small in a cutting orchard seems to accomplish an arresting of maturation. Furthermore, it may be possible to fix different maturation stages of donor plants by the size at which they are hedged. It also seems that serial propagation (in which cuttings are taken from recently rooted cuttings rather than from long-maintained donor plants) may arrest maturation. It may be possible to grow cells from mature trees in culture, change their maturation state, and then recover juvenile plantlets from the cultures. This technique might be helped if we better understood the physical and chemical events associated with meiosis and fertilization, for that is how and when mature plants normally produce juvenile offspring.

The Current Reforestation Situation — The use of grafts or rooted cuttings for large-scale forest planting has been proposed at intervals in the past, and indeed has been accomplished for centuries with such non-coniferous species as cottonwood and willow. Only Japan has extensively used this technique with conifers, most notably with *Cryptomeria*, their national tree.

Within the past few years, Finland, and Lower Saxony in West Germany, have moved out of the pilot-plant stage, producing hundreds of thousands to slightly over a million cuttings of Norway spruce (*Picea abies*) per year for reforestation. New Zealand is in the pilot-plant stage, rooting tens of thousands of radiata pine (*Pinus radiata*) per year. In western United States and Canada, we are entering the pilot-plant stage with western hemlock (*Tsuga heterophylla*), coast redwood (*Sequoia sempervirens*), giant sequoia (*Sequoiadendron giganteum*) and douglas-fir (*Pseudotsuga menziesii*), with other species not far behind.

Two recent symposia have been published and are now available. They are:

1974 Special Issue on Vegetative Propagation. *New Zealand Jour. of Forestry Science* 4(2):119-458.
1976 Symposium on Juvenility in Woody Perennials. *Acta Horticulturae* 56(May):1-317.

PROPAGATION TECHNIQUES FOR *MAHONIA* × 'ARTHUR MENZIES'

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In late September 1961, the Strybing Arboretum, San Francisco, sent us a group of seedling *Mahonia* plants raised from *M. lomariifolia* seeds. These were grown for a year or so in the cold frames, then transferred to the lathhouse as they increased in size. When this last move was made one plant seemed to have a very different leaf from the rest and we speculated that it might be a hybrid, perhaps with *M. bealei* since the shape of the leaflets suggested that species. Our suspicions of its mixed parentage were strengthened in December 1964 when a drop in temperature to 11°F. and continued below-freezing conditions for several days reduced all its sister seedlings to brown pulp, but left it nearly untouched.

When this plant first flowered in late December 1967, we made a careful analysis of it and felt that we were correct in assuming the parentage to be *M. lomariifolia* × *M. bealei*. In order to be more certain we sent an inquiry to Strybing Arboretum to find if *M. bealei* or some other *Mahonia* was within pollinizing range of the seed plants. We then learned that the seed did not come from plants in the Arboretum, but rather from the garden of Mr. Arthur Menzies, Supervisor of Plant Accessions for the Strybing Arboretum. He, too, felt that the hybrid "definitely is a *M. lomariifolia* × *M. bealei* hybrid" since he did not have *M. japonica* in his garden.

This question of parentage is of some importance since there is a *M. lomariifolia* × *M. japonica* hybrid extant in Great Britain, a fine plant called *M.* × 'Charity'. There has been no complete description of this clone published, but in comparing photographs of it with our *Mahonia*, certain differences become obvious. Its leaflets are slenderer and the racemes are somewhat lax, whereas they are nearly erect in our hybrid.

It was with very great pleasure, therefore, that we named this hybrid *Mahonia* × 'Arthur Menzies' in honor of one of the most knowledgeable horticulturists in California. *Mahonia* × 'Arthur Menzies' should prove to be a welcome winter flowering shrub and if it is as hardy as we think, it may be a valuable substitute for *M. lomariifolia* in places where the latter is not thoroughly hardy.

A complete description follows:

An erect, glabrous, several stemmed shrub about six feet tall at the end of five years.

The leaves are persistent, up to 55 cm long and 15 to 20 cm broad, odd pinnate, with 7 to 9 pairs of opposite leaflets. Leaflets dull green above, yellow-green below, thick, leathery, the basal pair 3 × 3 cm, subrounded, the others changing to ovate and thence to oblong ovate toward the tip, increasing in length from 4 to 11 cm long and from 3.5 to 4.5 cm broad; the base obliquely truncate and often imbricate with its opposing mate, the top spinose, long acute to shortly acuminate, often somewhat recurved and falcate; the margin spinose with from 3 to 5 spines on each side. The terminal leaflet ovate, usually larger, 9 to 14 cm long, 4.5 to 6 cm broad.

Flowers faintly scented, in several (7-9) erect fascicled racemes 10 to 25 cm long, appearing in late December and continuing through January. Floral bracts ovate, 4 mm long, 2 to 3 mm wide, greenish; pedicels 6 to 8 mm long. Flowers yellow (RHS colour fan yellow group 5A), nodding, campanulate, about 1 cm. broad at anthesis, sepals 9, in three concentric rows, the outer ovate, 1.5-2 mm long and 1 mm wide, the median 3.5-4 mm long, 2.5-3 mm broad, the inner 8-9 mm long, 4-5 mm broad, oblong ovate; petals 6, ovate to oblong ovate, 7-8 mm long, 5 mm broad, tip emarginate, glands two, distinct; stamens 6, 4-5 mm long, subapiculate, ovary green, cylindric, as long as the stamens and with a sessile capitate stigma. Fruit large, purple, similar to the parents.

Once we felt the plant was a new and useful ornamental we were faced with the problem of its propagation in some quantity. There were two reasons for this:

First, the genus *Mahonia* along with *Berberis* and × *Mahoberberis* include species which carry black stem rust of wheat and hence are under quarantine restrictions established by the U.S. Department of Agriculture. It was necessary to send a number of plants of *M.* × 'Arthur Menzies' to the Cooperative Rust Laboratory in St . Paul, Minnesota for testing. It was determined there that this hybrid was not susceptible to black stem rust and we received clearance to distribute it in May, 1974.

Second, we wished to distribute the plant to a wide range of gardens throughout North America for hardiness trials. So far no hard results are in on these plants, but at least one plant was recently seen thriving in a garden in the Philadelphia area.

In order to speed up propagation of this fine new plant we felt we must find a method which was both quick and not too wasteful of our limited amount of stock. Grafting was too slow while stem cuttings required cutting the parent plant too heavily. Leaf-bud cuttings seemed to be the best method and the following techniques were worked out.

The cuttings are best taken from the end of June to late July although other times also work. A branch is cut from the outside of the plant, and about 2/3 of each compound leaf is removed while still attached to the branch. This makes handling easier, reduces water loss from the cutting and saves room on

the cutting bench. The branch is turned upside down and the top leaf and its axillary bud is removed with a sharp knife. The cut is started about 3/4 inch below the bud and extends under the leaf base at a depth of about 1/16 inch and continues for another 3/4 inch above the bud. This sliver of wood is pulled free and the ends are trimmed to a total length of about 1-1/2 inches with the bud and leaf base about in the middle.

The entire leaf base is dipped into 0.8% indole-3-butyric acid powder (Hormodin #3) which is mixed with benomyl (Benlate) in the proportion of 1 part Benlate to 5 parts Hormodin powder. The excess powder is removed by tapping.

These cuttings are inserted into a rooting medium of 3 parts coarse river sand and one part ground peat in 8 or 10 inch clay pots with 14 to 16 cuttings per pot. The pots with the cuttings are then drenched with "Truban", 1 tablespoon to 3 gallons of water, to reduce the incidence of stem rot. The clay pots are used in favor of other containers since we are not going in for large production. The pots are then placed in a mist bench with a "Mist-O-Matic" control and bottom heat set at 70-72°F.

Rooting usually takes place in 7 to 8 weeks at which time the cuttings are potted on in 2½ inch pots using a standard potting mix and no additional fertilizer. These are placed on the greenhouse bench where they stay with little or no growth apparent for 4 to 5 months during which time the roots seem to be undergoing a hardening period. At the end of this time; a mild fertilization with a diluted fish material is applied and new growth is initiated shortly after. When this growth is hardened the plants are lined out in nursery rows. Under normal conditions, the cuttings will be 1½ - 2 feet tall at the end of the growing season.

PRODUCTION OF RHUBARB AND ASPARAGUS AS NURSERY CROPS

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In the last few years there has been a marked increase in the hobby of gardening throughout the United States. Seed companies, garden supply houses and canning jar producers, and we, as nurserymen, can attest to this increased activity. As nurserymen we are in line to cash in on this trend in many ways. Many of us produce or sell fruit trees and grapevines and other related items for this market. It may well be, however, that we are overlooking some items on which a good return can be made. Here at L.E. Cooke Co., we grow several items besides trees and vines that would be of interest to the home gardener, such as horseradish, artichokes, berry vines, Jerusalem artichokes, rhubarb and asparagus. When I tell you what is involved with two of these crops, rhubarb and asparagus, you may see a place for them in your operation.

Planting. In the past we have planted these two crops in the spring and in the fall; both dates have their advantages and disadvantages. Fall sowing of the seed allows one to get this job done during a slack season of the year for the bareroot grower, and at the same time cuts down on the spring rush somewhat. Also a well-done fall sowing provides much more growing time before harvest, which provides larger stock for market. On the other hand, a fall sown crop requires more attention during the winter season, a very busy time for us. In our area watering is critical during late December and January. Our soil also tends to compact severely during the winter rains; as a result, mulching fall seedbeds with sawdust is a must for economically uniform stands.

Spring sowing of seeds results in less cost of cultural practices due to the reduced time the crop is in the ground. Mulch is usually not necessary, which also reduces the cost. The primary disadvantage of spring sowing is the length of the growing season. If the spring is wet and planting is late, or if the spring is too cool and germination is slow, the season can be reduced critically. Rhubarb seems to develop enough size most of the time even during a short season, but asparagus needs the full allotment of time when it is spring-planted.

Our seed is planted by hand from shaker jars. The nearly 6 acres of rhubarb and asparagus we grow can be planted by three men in one day. Our asparagus is sown at approximately 33 lbs. per acre and rhubarb at approximately 12 lbs. per acre.

This seedling rate is based on 44-inch row spacing. The seed is sown ½ to 1 inch in the spring or 1 to 2 inches in the fall.

Cultural Practices. Cultural practices on these two crops are very nearly the same. Prior to planting, the soil is fumigated with methyl bromide. The soil is then prepared for ground application of super-phosphate and soil sulfur. The land is then bedded and the seed is sown. Once the seedlings are up, the most important thing one can do is to keep the water on them. Depending on the weather, approximately two inches per week is necessary. One can fail with asparagus at this point if the soil becomes too compacted or too dry for good root development. I saw the best top growth of asparagus the same year that the roots failed to develop sufficient length to sell. To solve this problem we make sure that the water soaks completely across the row each time and two to three times per year we rip every middle 18 to 20" deep. In September the water is taken off to harden the plants for early October digging. The tops are still green but they are sufficiently hard to be dug and stored successfully. We take advantage of the ground that we harvest these crops from to plant seedlings the next year, especially those species sensitive to methyl bromide fumigation. Regrowth of the asparagus or rhubarb is easily handled.

Harvest. The asparagus crop consists of two main cultivars on approximately three acres from which we harvest approximately 350,000 crowns. These are dug one row at a time and moved into the shade where the tops are removed. There they are graded, counted, tied, dusted with captan and packed in wire bound crates. They are held in the shade in an area where they can get good air movement until they are shipped. The rhubarb is grown on 2.75 acres from which we can harvest approximately 145,000 sections. These are dug and divided, if necessary, then packed and stored the same as asparagus.

ELM CUTTINGS FOR BONSAI TRAINING

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Hortica Gardens is a small mail order nursery selling, primarily, material to be used for bonsai training. All plants are container grown. Generally some preliminary pinching and pruning is done to make them more acceptable as bonsai subjects.

Two popular plants for bonsai training are Chinese elm (*Ulmus parvifolia*) and Catlin Elm (*Ulmus parvifolia 'Catlin'*). Although elms are often propagated by seed, it is more convenient to root cuttings. For the 'Catlin' elm, of course, vegetative propagation is necessary to insure identity of a true cultivar.

Chinese elm cuttings are made in spring and summer. Usually the cuttings are 7.5 to 15 cm long. The bottom two or three leaves are removed, leaving a minimum of 5 leaves at the top. ("three leaf" cuttings will root, however) Cuttings are made from new shoots when they are 15 to 30 cm long. Longer shoots may be made into two or three cuttings. If the tip growth is very soft, it's best to cut it off, since it will probably wilt and die back in the cutting box. Very sharp pruning shears are recommended for making elm cuttings because of the tendency for the bark to peel off in long strips when the cutting edge is dull.

Cuttings are collected in the growing area during the early morning hours. They are cut to length and the bottom leaves are removed before putting them in a closed can with a moist atmosphere. (Provided by a piece of wet paper towel)

Usually within an hour the cuttings are taken to a cool shady area for insertion in the rooting medium. Cuttings are treated with 0.4% alpha naphthyl acetamide in talc and inserted into a mixture of 50% perlite and 50% vermiculite. Propagating boxes 43 × 63 × 13 cm are used. Each hold about 300 cuttings. After filling the box, a removable top section and filon cover are put in place and the assembly is set outside in partial shade. Even in hot summer weather watering is only necessary every three or four days. Elm cuttings have also been rooted in flats under intermittent mist. However, there seems to be no great advantage in using mist, so most of our elm cuttings are rooted in propagating boxes.

Cuttings are ready to be potted up from 60 to 90 days after insertion. Usually they are put in 7.5 × 10 cm cans. Over a period of two weeks they are gradually shifted from full shade to 40% shade and then moved to the growing area which is par-

tially shaded by deciduous oak trees. The rooted cuttings are pruned every few weeks during the growing season to insure a compact "twiggy" plant with reduced leaves 1.5 cm long, or less. New shoots, 7.5 to 15 cm long, are cut back so that one to three leaves remain.

After six months to a year in the can, the roots are pruned to encourage the development of a flat, bushy system, suitable for planting in a shallow container. The trees are then repotted in the same can, a bigger can, or a smaller can. Care is taken to plant the tree so that the top of the root system is at or slightly above soil level. This pruning and repotting procedure is continued from two to five years, resulting in a final product which varies from 5 to 40 cm in height.

The intensive pruning carried out on these trees results in a very dense, twiggy top growth which may cause some problems. Undirected overhead water tends to slide off to the side and may largely miss the pot. Hand watering with a hose overcomes this. If the cans are closely spaced, the lower limbs may not get enough light and die back. Obviously, spacing the cans and occasional rotation will fix this problem.

Catlin elm cuttings are taken any time during the year. However, those taken in the winter don't grow very much until the weather warms up. Other elms that have been grown as cuttings include the cork bark elm (*Ulmus alata*), *Ulmus davidiana*, and the tiny leaved Hokkaido elm. (3 mm long leaves)

EFFECT OF NITROGEN AND CLIMATIC FACTORS ON SEASONALITY OF BANANA PRODUCTION IN HAWAII[1]

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Abstract. Planting material ("seed") of 'Williams hybrid' ('Giant Cavendish') was grown rapidly from frequent irrigation and nitrogen applications, using vigorous sword suckers, trimmed and heat-treated to control burrowing

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[1] Published with the approval of the Director of the Hawaii Agricultural Experiment Station as Journal Series No. 2065.

[2] Professor of Horticulture and Professor of Soils, respectively

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nematode (*Radopholus similis*). Within 12 months each corm had produced 4 to 6 clean well-developed sword suckers.

Bananas grown with high levels of nitrogen produced more and heavier bunches. Production peaks were compared at low, medium and high nitrogen rates.

Growth rates were greatest from May through October when solar energy averaged 424 gram cal./cm²/day and mean maximum-minimum temperatures were 28.5°C (83.4°F) and 22.8°C (73°F) respectively. Growth rates were lower from November through April when solar energy was 257 gram cal./cm²/day and maximum-minimum temperatures were 26°C (79°F) and 18°C (66.9°F). Rainfall of about 1300 mm (42") was supplemented by low-head sprinkler irrigation. Nitrogen, solar energy, and available water appeared to be the most critical factors under Hawaii conditions in banana production.

INTRODUCTION

This research was initiated with 'Williams hybrid' banana to determine critical levels for the principal nutrients under Hawaii conditions. Banana growers were shifting to 'Giant Cavendish' from 'Dwarf Cavendish' or 'Chinese' because it produced higher yields and the fruit had a longer shelf life. Banana uses large amounts of nitrogen and potash. Therefore, these elements were given primary attention in this study. Results from the first crop have been published (22). This report covers three years of harvest data.

In Australia, Summerville (16) found that the growth rate of banana from peepers on the corm to a fruiting plant ready to harvest was largely determined by the nutritional status of the plant during the first 3 months when the meristem was developing. The size of the meristem largely determined the size of the bunch produced. The corm expands into a mat over a period of 1 to 2 years, storing nutrients and carbohydrates. It is from this mat that suckers and shoots develop.

Bananas are propagated vegetatively from these young suckers. Sword suckers or large shoots make the best "seed" (5, 15). Figure 1 shows the 3 types of suckers. Peepers and water suckers have less stored food and smaller meristems and do not grow as fast as sword suckers. Propagating material was taken from virus-free mats and made free of burrowing nematodes (*Radopholus similus*) by trimming from the corms all discolored tissue and immersing the corms in hot water 50-55°C (122-130°F) for 15 to 20 minutes. Detail of the procedures have been published by Loos and Loos (12) and Trujillo (17). Figure 2 demonstrates the trimming procedure.

Figure 1. Banana propagating material, left to right: *Peepers*, suckers just starting to grow; *Sword Suckers*, with narrow leaves and enlarged corms; *Watersuckers*, broad leaves, slender pseudostems, and small corms. Sword suckers are the preferred planting material.

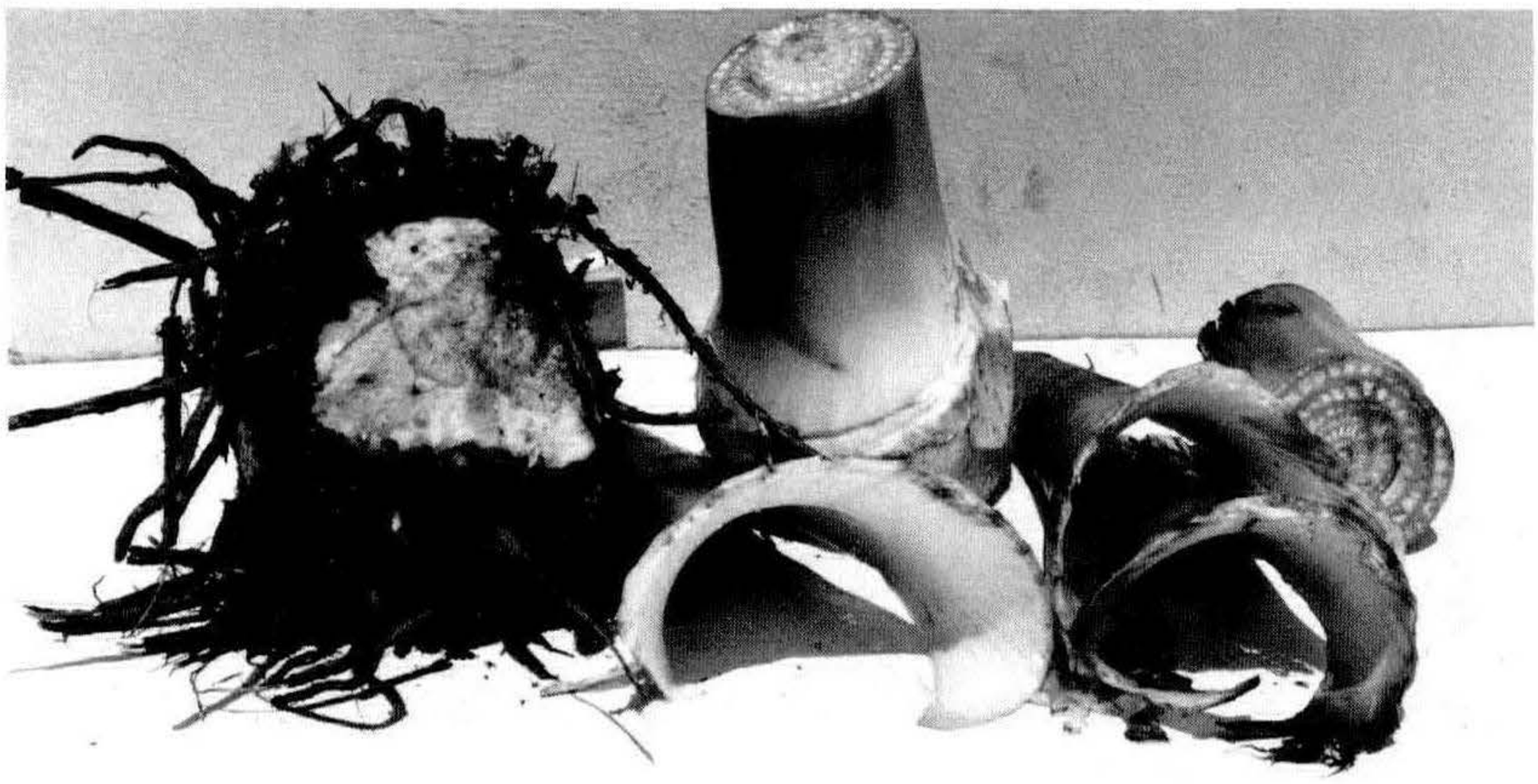

Figure 2. Banana corm (left) showing black lesions caused by the burrowing nematode. Corm (right) ready for hot water treatment for nematode control; all discolored tissue removed. Pseudostem cut back to 6″; 3 outer leaf sheaths removed.

REVIEW OF LITERATURE

Large amounts of nitrogen (N) and potassium (K) are used by the banana and lesser amounts of phosphorus (P), calcium (Ca) and magnesium (Mg) (16). During development of the fruit considerable K is taken up by the plant (16). Twyford (20) found a Cavendish plant crop produced, in 9 to 12 months, 100 to 150 tons per acre fresh weight of organic matter, including 8-14 tons of bananas. Nutrients taken up in a year, in pounds per acre, were: N, 400; P, 48; K, 112; Ca, 300; and Mg, 156. Croucher and Mitchell (6) working with 'Gros Michel' for 8 years, found responses to three major nutrients: N, P and K. Warner, *et al* (22) found that N fertilizer increased number of hands/bunch, finger length and weight and greatly reduced the days from planting to shooting. Butler (4) found yield responses only to nitrogen with 'Gros Michel' on exceptionally rich alluvia. In Jamaica, with other experiments, Butler found no advantage to organic manures. He found adverse effects from applying too much potash and saw no response from phosphate, even in low phosphate soils.

Twyford and Walmsley (21) found that fertilizer required by 'Robusta' bananas to be 2.5 kg/mat. of a 9:9:35 mixture. They recommended that applications be frequent and large the first year to rapidly attain high yields (50T/ha).

The number of leaves is important for filling the bunch. To produce a 50 lb. bunch 35 to 40 leaves are needed during the life of the shoot (2). Yields are depressed and delayed by loss of leaves from wind or leaf spot disease (*Mycosphaerella musicola*). In Hawaii, Black leaf streak disease (*Mycosphaerella fijiensis*) can be just as destructive (13).

Leaf analysis has been a useful tool in plant nutrition. Workers investigating 'Dwarf Cavendish', 'Poyo' and 'Lacatan' (Jamaica) have sampled the third fully expanded leaf at shooting (9, 10, 14). Others report work with the 'Giant Cavendish' banana (3, 18, 19). From these reports, critical concentrations of some nutrient elements can be tentatively set as percentage of dried leaf samples, as follows: N, 2.6%; P, 0.20%; K, 3.2%; Ca, 0.55%; and Mg, 0.40%.

Climatic factors have an influence on growth and production of bananas. Temperature affects rate of growth. Daudin (7) from Martinique showed the effect of altitude on time from planting to shooting; sea level up to 450', 6-7 months; 600 to 1200', 9-10 months; temperature 2°F lower; 1300 to 2,100', 11-13 months, temperature drop 5°F. In winter, fewer leaves are produced and the rate of flower emergence is much slower.

Bananas need a continuous supply of water for good production. Two inches per week is considered essential. Berril (2)

reported periods of drought or low temperatures reduced growth rate and flowering. Best yields were obtained with soil at 75% of moisture holding capacity (1).

MATERIALS AND METHODS

Our experimental planting was made in July, 1971. The first crop was harvested in May and June, 1972. Before planting, the corms were pared and heat-treated to control the burrowing nematode (*Radopholus similis*) and planted in a clean nursery. Figure 2 shows a nematode-infected corm and one trimmed and ready for heat treatment. A year later when good sword suckers had developed, they were dug and planted in a continuous function experimental design (8).

Forty-eight corms were planted in blocks of 6 × 8 plants. Nitrogen applications were made in 6 increments in one direction and potassium in 8 increments at 90° to the N. Thus every plant was an experimental plot and received a different combination of N and K. There were 8 blocks; 4 received P and 4 did not.

The relative amounts of fertilizer added for the various treatments were always in a fixed ratio. For N, the relative amounts were 0, 0.1, 0.3, 0.5, 0.7 and 0.9 (Table 1). Relative amounts of K were 0, 0.1, 0.3, 0.5, 0.7, 0.9, 1.1 and 1.3. The plant in each block with treatments N4K5 was used as a control. Monthly leaf samples were taken from the 3rd youngest fully expanded leaf of the dominant sucker of this mat. A 10 cm strip was taken from each side of the leaf at its center. The samples were dried, ground and analyzed for N and K. When the leaf content of N or K dropped near the critical level, more N and/or K was applied. The critical levels were 2.6% for N 3.2% for K.

Table 1. *Banana leaf nitrogen percentage. Average of 30 monthly means from 6 N treatments, and yields in metric tons/hectare.*

N Treatments	Low		Medium		High	
	N_1	N_2	N_3	N_4	N_5	N_6
Relative N rates	0	1	3	5	7	9
Urea, g/mat	0	40	120	200	280	360
Leaf N%[z/]	2.15	2.18	2.31	2.45	2.55	2.69
MT/ha/Mo[y/]	4.2	4.6	6.1	6.5	7.3	7.5
MT/ha/yr[y/]	50.1	55.2	73.2	78.5	87.4	90.3

[z/] All treatments total 3,069 shoots, 30 months.
[y/] All treatments total 4,111 bunches, 36 months.

Leaf samples were also taken from each plant at shooting. When the bunch was mature, 3 to 5 months later, it was har-

vested and weighed (22). Measurements of new shoots and the harvest data of mature bunches were recorded weekly.

Solar energy, rainfall and temperatures at Waimanalo fall into six month periods; summer, May to October; and winter, November through April. Solar energy averaged 257 gram calories/cm^2/day in winter and 424 in summer. For the same periods 5 year mean rainfall was 215 mm (0.15″) and 734 mm (29.1″). The maximum and minimum six month temperature means for 5 years are listed in Table 2. The differences are not great but for bananas, a few degrees is important especially around 20°C (68°F) as was shown above by Daudin (7).

Table 2. Waimanalo, Hawaii; summer-winter temperatures in degrees Celsius.

Year	May-Oct.		Nov.-Apr.	
	Max	Min.	Max	Min.
71-72	28.5	21.9	25.7	19.2
72-73	29.0	22.0	26.1	19.0
73-74	28.2	21.0	26.9	19.9
74-75	29.6	22.0	25.7	19.8
75-76	28.1	21.7	25.7	19.8
Avg.	28.7	21.7	26.0	19.6

Rainfall in Hawaii often is limited to tradewind showers. The clouds reduce solar energy without producing effective precipitation. Most effective rainfall comes from 2 or 3 tropical storms per year which come from the south. The irrigation used to supplement rainfall is usually adequate but is not always available. The summer months of 1974 were very dry and sufficient supplemental water was not available. Less than 95 mm (3.8″) of rainfall was received in July, August and September that year. This was reflected in the banana yields shown in Figure 3 and reduced the uptake of nitrogen in the leaves (Figure 4). Growth was reduced and fewer new leaves were produced.

RESULTS AND DISCUSSION

The nitrogen treatment data is summarized in Table 1. The relative rates and actual rates per application in grams of urea are presented. The mean N content of all leaf samples for each treatment shows gradual increase from N_1 to N_6 but the control plants often fell below the 2.6% N critical level. This indicated our nitrogen applications were not frequent enough. Likewise the yields were less than anticipated. Treatment N6 was to be

an excessive rate, which it was during the first year of production. Technical problems with obtaining foliar analyses promptly delayed the treatment applications.

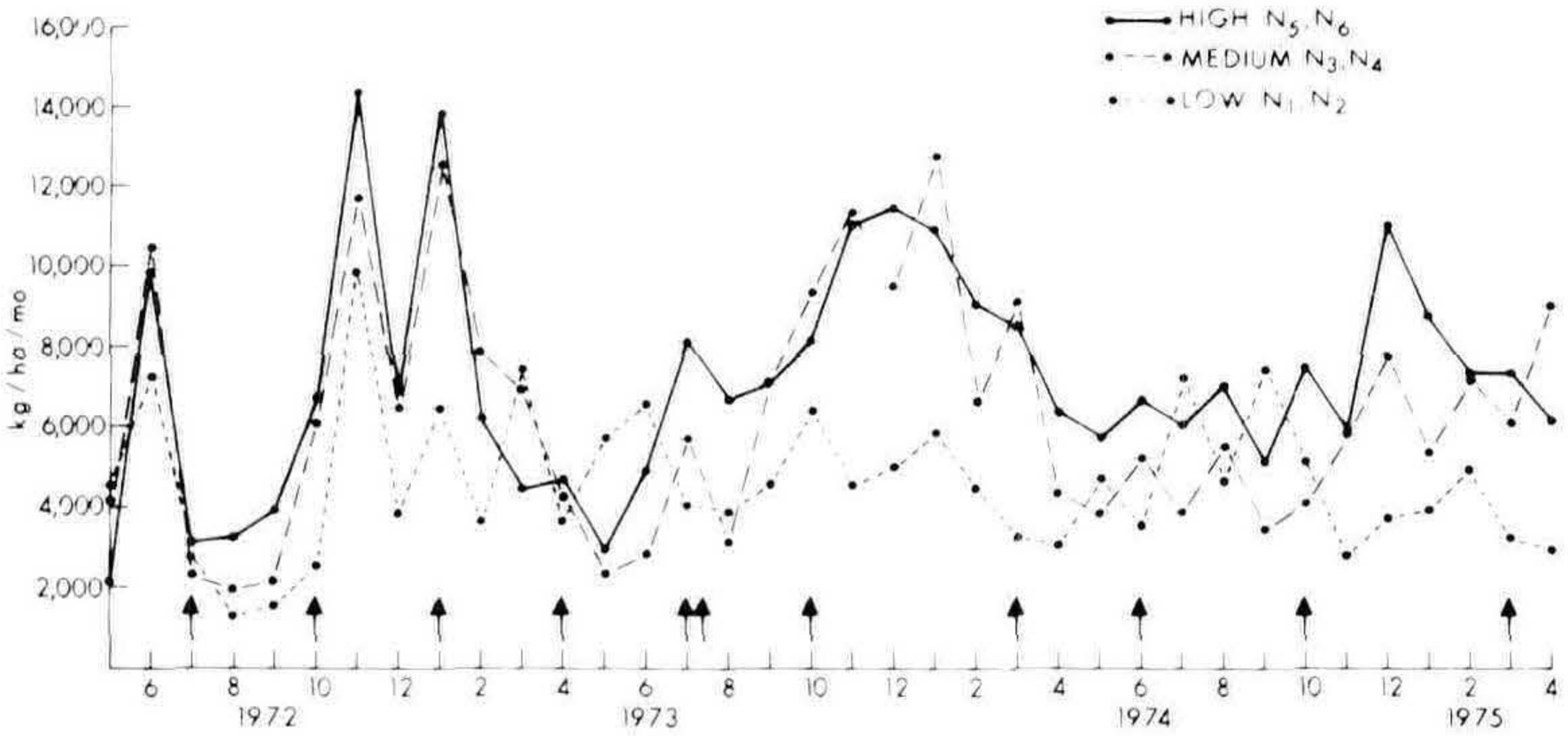

Figure 3. Yields of bananas during 3 years as influenced by levels of nitrogen fertilization. Each level of fertilization is the mean of 2 nitrogen rates. Arrows indicate time of nitrogen applications. Earlier nitrogen applications were made in August and December, 1971, and April, 1972.

The harvest data of each treatment were totaled monthly. Nitrogen treatments, N_1 and N_2 were combined as *low* treatment, N_3 and N_4 as *medium*, and N_5 and N_6 as *high*. The results are shown for 36 months in Figure 3. The arrows at the bottom indicate the time of nitrogen fertilizer applications. The production peaks of all three N treatments for the first 18 months were similar with high N treatment showing highest production and low N the lowest. The peak of June 1972 was not unexpected since the corms were all planted 11 months before. The double peaks in November, 1972 and January, 1973 were artificial because of uneaven harvests. They should be one peak because November and January each had 5 harvest dates and December only 3. After November, 1972 the low-N treatment plants had exhausted residual fertility in the soil and production peaks were smaller and irregular. The summer of 1974 was very dry and irrigation water was inadequate, as mentioned above. The soil was so dry that the plants were not able to take up nitrogen effectively. This was evident from Figure 4 where the leaf N content in August and September dropped sharply at all 3 N levels.

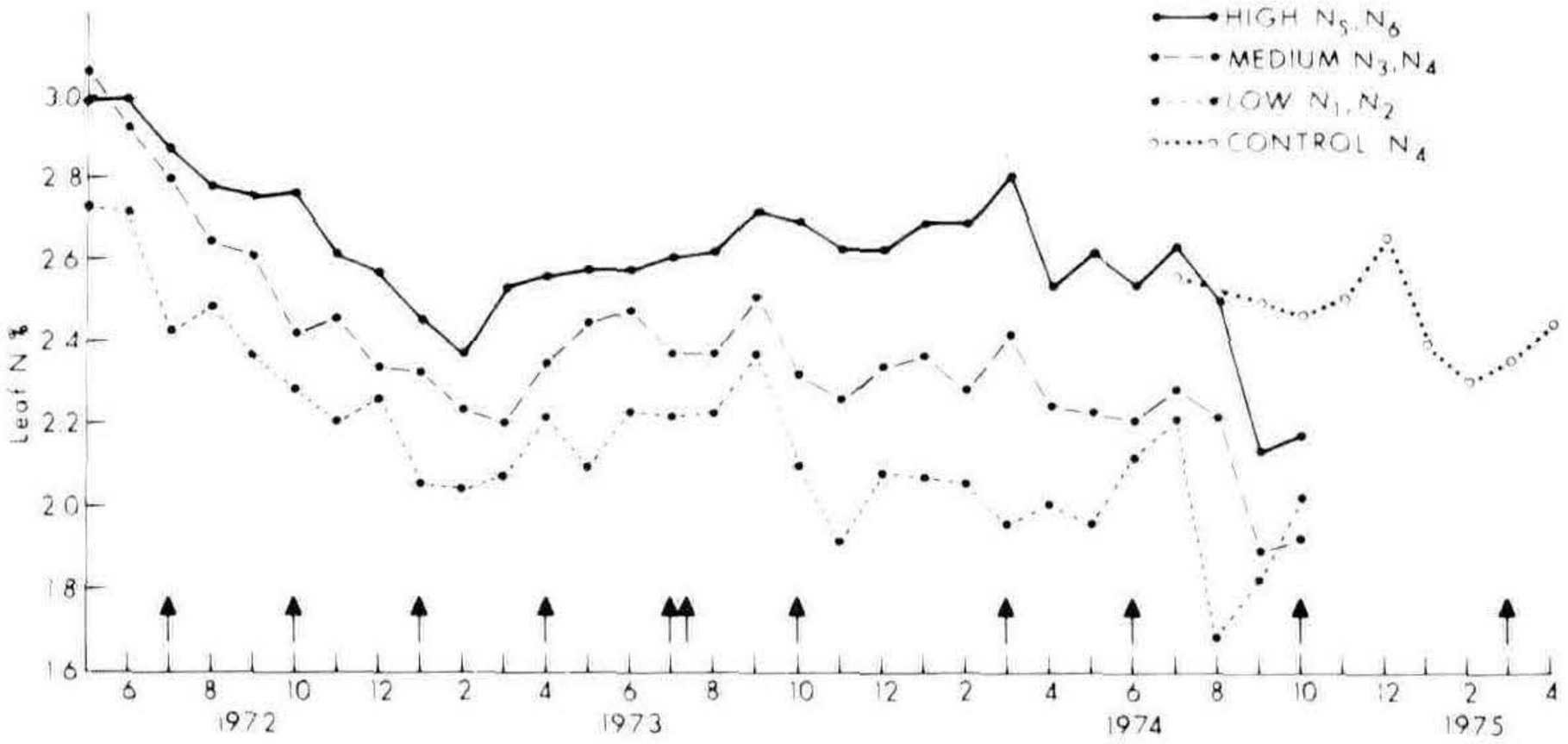

Figure 4. Banana leaf nitrogen percentages during 2 1/2 years as influenced by level of nitrogen fertilization. Each level of leaf nitrogen is a mean leaf N content of two application rates. Leaf samples taken at shooting are plotted as of the harvest date of the bunch some 3-6 months later. Leaf sampling was discontinued June 30, 1974, except for 8 monthly control samples of the N_4K_5 which are plotted on the dates the leaf samples were taken. Arrows indicate time of fertilizer applications.

The higher N treatments increased the number of bunches produced, the weight per bunch, and the total weight of fruit. Table 3 shows this clearly. The high number of bunches in N Rate 1 reflects border effects. Guard rows have since been planted to reduce it. The kg/bunch increased from 15.6 in N Rate 1 to 33.5 kg in N Rate 5 and decreased in N Rate 6.

Table 3. Effect of nitrogen rate on bunch weight.

N Rate	No. bunches	Kg total	Kg/ bunch
1	707	11,002	15.6
2	594	12,377	20.8
3	687	19,601	28.5
4	668	21,813	32.7
5	700	23,444	33.5
6	767	24,179	31.5

The number of healthy leaves a banana plant has affects the vigor of the plant and the size of the bunch. After the dry summer in 1974, plants had lower vigor and fewer leaves. October and November had moderate rains which favored build-up of banana leaf streak disease. December was very dry but January had 275 mm (11") of rain. No fungicide control measures were taken and the disease became severe. Leaf counts at

harvest in early 1975 are compared with those of January to April, 1974 in Table 4. In 1975 the leaf numbers continued to decline to about 2.7/plant compared to over 9 leaves in 1974. The leaf count was lowest in the low N treatments. The 1975 yields were considerably lower in January and February, than in 1974. However, the cause and effect needs more study.

Table 4. Healthy banana leaves/pseudostem at harvest vs N rate. (1975).

N rate		Jan.	Feb.	Mar.	Apr.
1974	Low	9.1	9.2	9.2	8.3
	Med.	9.4	9.8	9.7	9.3
	High	10.4	10.1	10.1	9.3
1975	Low	6.0	3.9	3.1	2.6
	Med.	6.4	4.7	4.1	2.8
	High	7.6	5.3	5.1	2.9

It has been demonstrated that rates of nitrogen fertilization are of primary importance in banana production in Hawaii but may be limited by inadequate moisture, low temperature and insufficient solar radiation. A biotic factor, such as the fungus disease, Black leaf streak, may also limit the effects of N fertilization.

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INSECT BIOLOGICAL CONTROL

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Biological control has been given a rather restrictive definition by some entomologists, who maintain that it applies only to the use of parasites, predators, and pathogens for the reduction of pest populations to tolerable levels. Others have chosen to expand its definition to include other technologies of a biological nature directed toward pest population reduction. I have followed the latter course.

As plant propagators, biological control has very little to offer you directly. Its greatest utility, based on knowledge to date, comes after the plants you have propagated are planted in the landscape, orchard, vineyard, or other growing site. Yet as plant propagators you properly have an interest in the kinds of pests which attack the crops you produce, the intensity of resultant damage, and the procedures necessary to alleviate pest infestations.

Parasites, Predators, and Pathogens. Our most important parasites are tiny wasps and flies whose adults deposit their eggs in or on pest insects. On hatching, the immature parasite proceeds to devour the pest before emerging as an adult from the dead host to begin the cycle again. A recent success story involved the release of the wasp *Trioxys pallidus* to combat the walnut aphid, *Chromaphis juglandicola*, in California.

A predator normally consumes a number of host insects before completing its development. The more significant predators include the ladybird beetles, green lacewing larvae, ground beetles, and assassin bugs. Also, birds, toads, and a variety of other animals serve an important role in a predatory capacity but these do not lend themselves easily to manipulation by man as do some of the insects which are predators. The first successful instance of the planned biological control of an insect pest involved the introduction in 1888 of a predaceous ladybird beetle, known as the Vedalia, from Australia for control of the cottony cushion scale, *Icerya purchasi*, on citrus trees in California.

Biological control by parasites and predators has the advantage over many other pest control methods in that it is self-perpetuating and therefore rather permanent, inexpensive to initiate, and contributes nothing to the pollution of our environment. It is most effective in dealing with pests which have been accidentally introduced from another country. Such introduced pests usually arrive and become established without

their natural enemies. Classical biological control, then, entails the search for and introduction of parasites or predators from the native home of the pest, and the release of these in the pest's new country of residence. Biological control is less effective in dealing with a native pest, for we have no where to go in search of its natural enemies. Unfortunately, a high proportion of the more important shade tree pests in the United States are native insects; therefore the outlook for biological control of these is rather dim. Yet even these native pests have a complex of native natural enemies, although they are not always effective in reducing infestations to acceptable levels. In such cases there are steps which can be taken to improve or augment this naturally-occurring biological control. For example, providing food sources such as nectar-producing plants can result in improved effectiveness of many parasitic wasps. Avoiding the use of broad-spectrum insecticides, especially during critical periods of parasite or predator activity, is another means of achieving the maximum benefit from naturally-occurring agents of biolgocial control.

Pathogens are disease-causing agents which can be manipulated by man to bring about biological control of pest insects. Our greatest experience has been with the bacteria. For many years, *Bacillus popilliae* has been commercially available for use in the soil for control of the larval stage of the Japanese beetle, *Popillia japonica*. *Bacillus thuringiensis* is widely available and effective against a variety of caterpillar pests of ornamental, fruit, vegetable, and field crops. At present much research attention is focusing on insect viruses as pathogens of pests. Like conventional chemical insecticides, pathogens must be thoroughly evaluated for safety to mammalian systems, and for environmental impact, before they can be made commercially available by industry.

Other Means of Biological Control. Beyond parasites, predators, and pathogens, other pest control agents or techniques exist which could properly be considered to fall under the definition of biological control, in that they effect biological systems in a way deleterious to pest insects:

Pest-resistant plants — These are plants with genetically-inherited traits which cause them to be unattractive to insects as a place to deposit their eggs, which are toxic to insects which feed on them, or which are able to support pest infestations without resultant intolerable damage. As examples, the European grape, *Vitis vinifera*, is highly susceptible to the root-infesting form of the grape phylloxera, *Phylloxera vitifoliae*, while the American grape, *Vitis labrusca*, is resistant to it. *Juniperus sabina* 'Tamariscifolia' is heavily attacked and severely damaged by the juniper twig girdler, *Periploca nigra*, but

many of the heavier-wooded prostrate junipers are tolerant to this pest.

Entomologists and plant breeders have worked alone and in collaboration with one another for years in an attempt to enlarge the number of pest resistant plant cultivars available to agriculture and forestry. Their record of success is not impressive, however, because of the long-term research commitment necessary and the fact that insecticides have been so readily available to handle almost any plant protection need. Yet with new restrictions and regulations on insecticide use, entomologists are giving increased research attention to the development of pest resistant plants.

Guidelines for the development of insect resistant ornamental plants depart from those recognized in agriculture and forestry. Whereas a breeding effort is needed to develop resistant corn, tomato, or tree fruit cultivars, a program of evaluation and selection of pest resistant ornamental shrub and shade tree species could serve many of our needs very well on a regional basis. In coastal California, for example, *Acacia verticillata*, *A baileyana*, and *A. podalyraefolia* are practically immune to the albizzia psyllid, *Psylla uncatoides*, where the species, *A. retinodes*, *longifolia*, and *melanoxylon* are very severely attacked by this pest. In Contra Costa and Alameda counties, California, the kuno scale, *Lecanium kunoensis*, devastates pyracantha. The use of that plant should be avoided there, and less pest-prone shrubs grown instead. *Cedrus deodora* or *C. atlantica* are much more pest-free than the overplanted and pest-prone Monterey pine, *Pinus radiata*, and *Ginkgo biloba* is almost free of pest problems wherever it is grown. When dealing with ornamental shrubs and trees, we can often make good use of alternate species of plants, so long as they have the appropriate characteristics of color, height, form, and texture for a given situation. Of course in the selection of ornamentals their susceptibility to plant diseases and other disorders must be given consideration as well.

Insect growth regulators — A new family of chemicals is being synthesized which mimic hormones and other substances naturally produced by insects which are essential to the insect's normal growth and development. When applied to insects at a critical stage of their development, these compounds de-rail normal growth processes and the insect dies, is malformed and therefore unable to reproduce, or is rendered sterile. One of these, Altosid®, is available for control of floodwater mosquitoes. When immature mosquitoes are contacted by Altosid, they are unable to transform to the adult stage, and die. Another compound, Dimilin®, disrupts the normal formation of chitin, an essential component of the skeletal covering of in-

sects. The considerable research efforts on insect growth regulators by university and industrial scientists almost certainly will turn up a variety of unique compounds for use in pest control in the years ahead.

Behavior modifying chemicals — The world to an insect is a chemical one, for virtually every aspect of its behavior is controlled by responses to chemicals. This includes orientation to food sources, the selection of a place to deposit eggs, the location of a mate, and its defense against natural enemies. Some of the chemicals so necessary for the wellbeing and survival of insects have now been identified and synthesized and are in an active state of investigation as means of controlling pest insects.

Pheromones are external hormones produced by most insects and which are essential for such activities as finding a mate, aggregation, and maintaining the integrity of social structures of bees and ants. Sex pheromones released by certain female moths have the ability to attract males of the same species from a distance of several miles. By releasing synthesized sex pheromones, we now have the means to detect very low levels of certain insects invading a new area by luring them into sticky traps. Using similar traps, we can more properly time the application of chemical insecticides because of the improved knowledge of when the target insects are active. Attempts are also underway to achieve direct control of insect populations by trap-out strategies, utilizing pheromones, or by disrupting successful mating of males and females through saturation of the insect's environment with a sex pheromone. The potential for manipulating insect populations by behavior-modifying chemicals appears very bright.

Other techniques — The use of crop rotation or other cultural methods, the release of sterilized male insects into the environment, and the use of genetically-altered insects can all be considered biological control procedures but in the interest of brevity their attributes will not be described.

Integrated Pest Management. With this broad array of biological control tools, one might ask why it is every necessary to employ conventional insecticides for pest control. The reasons are that biological control techniques are quite specific as to target insects, some are only regionally applicable, and the number of pests with which we must deal in agriculture and forestry is very large. Also, some of these techniques have only been uncovered in the past few years and it will require some time before their full potential can be discovered and exploited. Finally, the economic pest situation is continually changing — new problems are continually arising but the old ones seldom just go away. In all likelihood the use of conventional chemical

insecticides will remain an important component of pest control for many years to come.

Trends in pest control now are in the direction of integrated pest management. Because a single line of attack is often unsuccessful in the long term, methods of integrating two or more compatible techniques show promise for improvement in plant protection over the long term. Integrated pest management programs which have been developed thus far rely heavily on a biological control component, but chemical insecticides are used when necessary, and in a way least likely to disrupt the gains which have been made by biological control.

AERATED STEAM TREATMENT OF NURSERY SOILS

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Growers have become increasingly interested in soil treatment and in pathogen-free stock as they have realized that the ultimate sources of disease organisms are the soil (including water and nonliving organic matter) and living plants. Soil treatment may be accomplished by chemical fumigation or by steam. Destruction of microorganisms has been the objective of such treatments since they started in 1880-90, and recommendations have emphasized overkill rather than minimal effective dosage. There is now a marked trend toward minimal treatments and toward fumigants selectively toxic to pathogens so as to avoid creating a biological vacuum dangerously subject to reinvasion by pathogens, and so as to decrease formation of toxins injurious to plants.

Commercial soil steaming to control diseases and insects was begun in 1893. but the methods remained empirical for 60 years, with little scientific study or grower inventiveness. Critical investigations were published in England, Norway, and California in 1954-60. The studies on aerated steam at the first two places were made by engineers in an effort to reduce fuel consumption. Our California studies were aimed at avoiding the creation of a biological vacuum and production of phytotoxins. It has been known for 35 years that moist heat of 140°F for 30 minutes will destroy plant pathogens (except tobacco mosaic virus); treatment at higher temperatures therefore wastes energy and is biologically undesirable. Plant pathogens are more sensitive to heat than are many saprophytic microorganisms. Treatment at a temperature just sufficient to kill pathogens will leave

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a substantial microflora that will compete with and be antagonistic to any pathogen later accidentally introduced. A form of biological control of plant pathogens is thus provided.

Creation of a similar effect by fumigants and other chemicals now used has proved impractical. Highly specific chemicals are subject to the considerable risk of microorganisms developing resistance to them; such resistance to heat, which affects large metabolic targets, has not developed. A volatile fumigant injected into soil diffuses outward in expanding spheres, but, since it is sorbed by the soil, its concentration decreases progressively out from the point of injection. Treatment, therefore, is characteristically nonuniform through the soil mass, with overkill at the point of injection and undertreatment at the outer points. By comparison, the temperature of soil treated with steam or aerated steam is uniform throughout. The steam condenses on the soil until it reaches the injection temperature, then passes by and condenses on the next cool soil. BTU are released only at the point to be heated. The only variable is the time required for steam to permeate the soil, and with proper equipment and adequate steam flow this can be very short. Aerated steam is thus better suited to controlled manipulation of soil microflora than are chemicals.

Movement of Aerated Steam through Soil. Soil steaming is essentially the transfer of heat from a boiler to the soil. Aerated steam diffuses through the continuous labyrinthine pores of the soil to particles colder than itself, where the steam component condenses. It therefore moves as an advancing front (treatment temperature on one side and unheated soil on the other) that varies from an inch or less in width (with efficient high steam-flow rate or proximity to the input) to several inches wide (with low steam-flow rate or greater distance from the steam input). In this zone of heating the aerated steam mingles with the pore air, producing a mixture ever richer in steam as the temperature rises. The displaced pore air and the air from the spent aerated steam are pushed out, imparting their heat to soil particles as they pass out of the soil. A ready escape for this expelled air must be provided or the aerated steam will not penetrate, and the soil will not be heated.

Ground beds, therefore, usually cannot be effectively steamed by surface application because of the excessive friction to the downward and outward movement of the displaced air through the compacted soil beneath the bed and in the walks. By comparison, there is relatively unimpeded outflow of air through the bottom of a raised bench, and porous soil 10-12 inches deep may be readily steamed.

Since aerated steam penetrates very poorly into compacted or low-porosity soil, thorough cultivation to the desired treatment depth is required. For the same reason, clods should be screened from the soil or broken up by cultivation. Soil moisture beyond that required for good planting tilth decreases efficiency because of the increased heat capacity and diminished pore size. Dry soil should not be treated since weed seeds and spores of plant pathogens are more resistant to heat when they are dry than when moist.

Application of aerated steam from the bottom of the container is best done through buried pipes or an enclosed space (plenum) with a perforated upper plate on which the soil rests. To avoid restricting the air outflow, a tight tarp cover should not be placed over the surface until the soil air is displaced (i.e., until the soil has reached the desired temperature).

There is now a marked trend toward application of aerated steam to soil through a plenum at the top in order to reduce "blowouts" (eruptions of steam through chimneys of fluidized soil that bleed steam from the rest of the treatment area). Steam follows the path of least resistance. Downward "blowouts" tend to seal themselves with loose soil. Steam injected into a top or basal plenum moves along the walls of the treater faster than at the center. This tendency is diminished when the soil layer is no deeper than 24 inches, when a porous soil mix is used, and by using a relatively high steam flow rate.

Mixing air with steam dilutes it and lowers its temperature to any desired level. The ratio of air to steam at 212°F is 0:1 by weight; at 180°F it is 1.5:1; at 160°F it is 3.3: 1; and at 140°F it is 6.5:1. The lower the temperature desired, the greater is the amount of air required, and the poorer the mixture in heat content. The old steam treatments at 212°F/30 minutes had a very large margin (72°F) of safety, and even relatively careless treatment usually was effective. Even if the soil in portions of a bench was more compact or wetter than the rest, or the soil had large clods, they would almost certainly reach a minimum of 140°F. It is obvious that the margin of safety decreases with the treatment temperature. This situation is not different from other agricultural practices today that operate on closer tolerances and with greater precision than in the past. Abundant experience shows that after 212°F steaming, unheated areas may remain as foci of contamination if the work is improperly done. The difference between 212°F and 140°F treatment is, therefore, one of degree rather than type. Aerated steam moves in the same manner and rate through the soil as does pure steam.

How is Aerated Steam Produced? The simplest way to produce aerated steam is to join together a pipe of flowing

steam and one of flowing air so that the gases intermingle. If a needle valve is placed in each pipe, the total flow rate can be determined by controlling the steam flow, and it can then be adjusted to the desired temperature by manipulating the air flow.

The air is best supplied by a blower. The type of blower depends on the amount of frictional resistance in the system to the flow of air (i.e., static or back pressure). Straight blade centrifugal blowers are generally used because they are relatively inexpensive, rugged, and provide a static pressure (about 6 inches of water) sufficient for most soil steaming. Squirrel-cage blowers are not suitable because they supply only 2-3 inches static pressure. Higher pressures can be generated by centrifugal blowers with backward curved blades or by Roots's Blowers, but the cost is excessive, and the power requirement high. Piston compressors supply small volumes of air at high pressure, the reverse of needs for soil treatment. Venturis were used for a time, but are now rarely used. The size of the blower in cubic feet per minute, and the pressure it will delivery must be scaled to the job. If too small a blower is used, it will be impossible to bring the soil to temperature in 30 minutes, if too large, "blowouts" will become a problem. Table 1 will be useful in determining approximate blower size as well as boiler capacity.

Table 1. Flow rate of air and steam required to heat one cubic yard of U.C.-type soil mix to the indicated temperatures in 30 minutes at two levels of operational efficiency. Computed on the basis of soil and air temperature of 70°F, and soil moisture 15%.

Treatment temperature (°F)	Air-steam ratio (by weight)	30% Efficiency		50% Efficiency	
		Air (c.f.m.)	Steam (lb./min.)	Air (c.f.m.)	Steam (lb./min.)
212	0:1	0	7.80	0	4.68
190	0.9:1	80	6.57	48	3.94
180	1.5:1	123	6.04	74	3.62
170	2.3:1	170	5.47	102	3.28
160	3.3:1	220	4.94	132	2.96
150	4.7:1	276	4.37	166	2.62
140	6.5:1	336	3.84	202	2.30

Steam usually is injected into the air stream somewhat before it enters the treatment chamber, and the rate of steam flow is manually controlled by a needle valve. The air flow is controlled by a damper on the blower intake or a damper bypass on the blower outlet. In a typical installation the blower is connected to the treatment unit through a flexible wire-reinforced neoprene hose of about 6-inch diameter. A thermometer in-

serted into the tube at the point where it enters the treatment unit will indicate the temperature of the steam-air mixture. The thermometer must be accurate in the range used. Good quality chemical thermometers must be used, and should be calibrated against one of known accuracy.

The soil should reach the desired temperature in 30 minutes or less and be held at that temperature for 30 minutes. The flow may be reduced after the desired temperature is attained, and the steam shut off after the treatment period. The continued air flow will then rapidly cool the soil by evaporative cooling, permitting prompt use of the soil in planting. The temperature need not be brought below 90°F. An oiled fiberglass filter should be placed over the blower intake to remove dust from the air, at least during the cooling cycle, to prevent contamination of the cooled soil by dust-borne microorganisms.

Methods of Treating Soil with Aerated Steam. It is possible to treat soil with aerated steam by any of the standard methods used for soil steaming by nurserymen and florists.

Subsurface Steaming. Buried perforated pipes or tiles may be used for aerated steam, but the size of the pipes or tiles must be greater than for steam alone because the volume of gases at 140°F is 4.1 times that of steam alone, In the soil bin, mobile bin and potting bench, dump truck, and steam box types, a basal plenum should be used instead of perforated pipes to introduce the steam. This plenum should be 4-6 inches high and covered with a perforated steel plate or a strongly supported expanded metal screen on which the soil rests. The mobile bin and potting table with a basal plenum has been constructed by many growers, and an American commerical unit is also available.

Surface (Thomas) Steaming. This method is commonly used on raised benches. The aerated steam is fed tangentially into and near the bottom of a circular trap to centrifugally remove entrained water drops. On all surface types of equipment such a drier is necessary to prevent production of a wet spot below the point of injection. The dried aerated steam is then introduced under the canvas bench cover in the usual manner for the Thomas method. The cover must be held down on the bench with wood strips clamped to the sides, because of the great volume of aerated steam introduced. The method is almost worthless on benches with tight bottoms, or on ground beds with inadequate bottom drains, and should be supplanted by buried pipes under these conditions. A modification may be used on the mobile bin and potting bench by using a plenum lid on top, with the bottom plenum acting as an exhaust chamber. The outlet opening of the exhaust chamber should be the same diameter or smaller than the input opening of the in-

jecting plenum. Commercial New Zealand and Australian units are available in which the controls are completely automated.

Vault Steaming. Flats, pots, or other containers of soil are placed in a closed chamber or vault into which straight steam is released without pressure and mingles with the air. The temperature slowly rises as the air is expelled through cracks around the door or through an open release valve. Since the vault space is occupied by the air which mingles with the introduced steam, no air need be added until the steam-air mixture attains a temperature about 20°F below the desired treatment temperature. The blower is then turned on to establish the upper treatment temperature. It is not desirable that the vault be air tight unless the spent aerated steam is to be recycled through the blower. If the aerated steam is released into the top of the vault, it must be centrifugally dried, as for surface steaming; if it is introduced at the bottom, this is unnecessary as the vault will act as the water trap.

The containers in the vault should be separated by at least 1/2 inch in each direction to facilitated steam penetration. Heating the soil in the containers is largely from diffusion of steam into the exposed soil surface. The last point to attain temperature in a pot or flat is thus in the center about 2/3 of the distance down from the top. No container to be treated in a vault should hold more than a half cubic foot of soil.

Transit-type Concrete Mixers. These units have come into general use for soil mixing in nurseries and glasshouses, and more recently this operation has been combined with soil steaming. Since the soil is constantly tumbling through steam, and since the mixer is filled with air, this equipment in effect uses aerated steam. The time of injection of straight steam determines the temperature; when the desired temperature is reached the steam flow is decreased to a level just sufficient to hold the temperature for 30 minutes. The mixer *must* be less than half full for satisfactory mixing and steaming, and the surface of the drum should be insulated with a foam plastic.

Advantages of Treating Soil with Aerated Steam. There are several advantages in using aerated steam rather than 212°F steam in treating soil, some of which will appeal to one and some to another grower.

1) There is less chance of destroying soil microorganisms antagonistic to plant pathogens when treating at 140°F than at 212°F. There is, therefore, a reduced chance of an accidentally introduced pathogen luxuriating and causing severe disease loss. This biological buffering effect is a reinforcement of reasonable sanitation, not a substitute for it. This protective effect does not result when essentially sterile media (sand mined from

deep deposits, perlite, vermiculite) are used. The treatment selects microorganisms, it does not create them. The microorganisms that survive the 140°F treatment are largely in genera recognized to be potential antibiotic producers. The spores of these antagonistic bacteria and fungi are stimulated by 140°F treatment to greater germination and growth, increasing their relative proportion in the active soil population. Most weed seeds are also killed if the soil is kept moist for three days prior to treatment.

2) The toxicity of soil to plants that is often induced by steaming to 212°F does not occur when treated at 140-160°F. In such toxic soils seedlings may be killed or severely injured, and yield of mature plants may be reduced. The usual experience of growers is that an increase in size and vigor of plants results when soil treatment temperatures are lowered. For example, water-soluble manganese is released from the soil colloids by excessive heating. Some soil fumigants also leave a toxic residue (e.g., methyl bromide is injurious to carnation and snapdragon).

3) Because the temperature is raised only about half as high at 140°F as at 212°F, there is a substantial reduction in the quantity of steam used. This means lowered cost, greater treatment capacity from a given boiler, or both. The saving in fuel will largely offset the expense of supplying the necessary air for treatment.

4) The soil cools more rapidly to temperatures suitable for handling or planting when treated at 140°F than at 212°F. By continuing the air flow after treatment the temperature may be lowered even more quickly by evaporative cooling.

5) Workmen are not burned in handling aerated steam at 140°F, as they may be at 212°F, and experience less discomfort. Several growers have indicated that they would continue the use of aerated steam for this reason, even if there were no other advantages.

6) Plastic pots and small divided inserts for flats can be safely treated at 140°F without deformation, and some withstand 160°F. This permits treatment of the soil in the containers, and reduces handling following treatment with its attendant opportunity for contamination.

7) The "weed molds" (*Peziza ostracoderma*, *Trichoderma viride*, *Pyronema confluens*), prevalent on soil treated at 212°F/ 30 minutes, are largely suppressed on soil treated at 140°F by the surviving resident antagonistic microflora.

Epilogue. As with any new method not fully understood, some misconceptions have arisen about the use of aerated steam

for soil treatment. It is thought to be expensive, complicated, and difficult to use. However, almost any treatment equipment used for 212°F steam can be used for aerated steam. The only additional equipment needed is a blower, and the added expense is minimal. Operation is similar to, and no more complex than that for straight steam. Grower experience in many different areas in the last 14 years has been in accord with these facts.

Some have mistakenly thought that, because of remaining soil antagonists after aerated steam treatment, sloppy sanitary operations can be allowed. This treatment is supplemental to good grower practices, not in place of them.

Aerated steam is today a practice of demonstrated feasibility, economic desirability, and beneficial though still largely unexplored biological potential. Since the ultimate test of any soil treatment is the subsequent contamination by pathogens, the use of aerated steam treatment is here to stay.

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QUESTION BOX

WILLIAM SNYDER: Now, do we have some questions for our panel?

VOICE: In the case of certain of these biological control tools, particularly the behavior-modifying chemicals and the insect growth regulators, are there any side effects on the environment?

CARLTON KOEHLER: We don't recognize many, but I should point out that in the case of some of the behavior-modifying chemicals, in the case of pheromones, for example, that since these are used to either control, repel, attract, or mitigate they are considered pesticides by the EPA and, there-

fore, must be evaluated as any pesticide. So there is going to be a long delay in these materials appearing commercially because they have to undergo a series of tests, even though they are naturally-occurring products. But I know of no particular environmental impact that any of these classes of compounds is going to have.

VOICE: When you are using insects to control other insects, once the beneficial insect has consumed the pest insect, do not the beneficial insects move on?

CARLTON KOEHLER: The answer is yes. They have got to have hosts on which to feed. So you always must have a residue of insects in order to keep these things going.

PAUL MOORE: Dr. Baker, you didn't mention the length of time for the aerated steam treatment. Are we to infer that a 30 or 40 minute treatment at 140°F is correct?

KENNETH BAKER: Yes, I am glad you raised that point. In order to simplify the situation we have tried to standardize on a 30 minute time interval, and use the temperature as the variable. If everybody uses a 30 minute interval, at a certain temperature you know that you will achieve a certain result. If you suggest 135°F for 35 minutes, for example, you have a chaotic mess. We are trying to eliminate the time variable by standardizing it.

VOICE: What are the common names of the fungicides mentioned?

ROBERT RAABE: Benomyl is sold at the present time principally as Benlate. Ethazol is sold primarily by the name Terrazole if it is manufactured by Olin Company; if it is produced by Mallinckrodt it is Truban or Koban. Koban is used principally on turf; Truban is registered for use on ornamentals. Truban can come either as a wettable powder or as an emulsifiable liquid, either of which does an excellent job. Diazoben is sold principally as Dexon. Thiophanate methyl is marketed under the name of Cercoban M or Topsin M or Xyban, depending upon who makes it.

VOICE: Can you use Ban-Rot at 6-month intervals?

ROBERT RAABE: Ban-Rot is a mixture of Truban and thiphanate methyl. It is a very good mixture because it does cover a range of different fungi which are all important. The length of time that they will last in the soil will depend upon how you are using your soil. If you have soil in containers and you have a disease problem, we find you should use these materials at approximately one-month intervals, although you may skip and use them at two-month intervals. It depends upon how

much disease control you get when you use it and how many disease-producing organisms you have present. You just sort of have to feel your way along.

VOICE: Can you treat carnation cuttings to control *Botrytis* with a dust material as readily as with a solution?

ROBERT RAABE: I don't know. We haven't tried it. Maybe we should try. We have used dusts in other areas and generally we find we do not get as good coverage with a dust as we do with the dip, therefore we do run into some problems. We haven't tried it on carnations. I think it might be a good idea to try.

PHILIP BARKER: I would like to ask Dr. Baker a question. In the absence of a boiler, what type of portable steam generator do you recommend?

KENNETH BAKER: One should explore the availability of stand-by boilers that are operated in most cities that have any sort of manufacturing or commercial operations. You can have them brought in to supply steam at so much an hour or a day. The Clayton Boiler Company has truck-mounted boilers in cities that have need for them. One of the common misconceptions is that steaming is an expensive operation; but if you work it out on a pro rata basis it actually is no more expensive in the long run than using chemical fumigation, or any other form of soil treatment. Think of it on a 10 year basis on the cost of the boiler. Even if you borrow the money, it still pays off. But if there is a possibility of using one of these rental services, I would do it. You can find these rental boiler companies listed in the yellow pages of the phone book. These are commercially available in case a boiler breaks down and will provide boiler service while their own equipment is being repaired.

Using the right size boiler to do the job is a matter of sizing it to the number of cubic yards of soil to be treated at one time.

VOICE: Dr. Baker, could you explain further about filtering the air into the boiler?

KENNETH BAKER: You do not inject air into the boiler; you inject the steam into the air flow from the blower. The filter simply goes on over the input of the blower. The fiberglass that is sprayed with oil — just as you do with the air filter in your car — is to keep out dust.

BRUCE BRIGGS: Where are we in terms of biological control of plant pathogens?

KENNETH BAKER: Essentially it comes down to two things that are being done. One is manipulation of the soil environment to make it more favorable for antagonistic organisms already present. An example of this is provided in the state of

Washington in control of fusarium foot rot of wheat. They know that if their moisture level declines appreciably — it doesn't have to go down very far — the antagonistic bacteria present in the soil become inactive — go into a spore stage. These bacteria, while active, suppress *Fusarium*. The problem thus becomes one of keeping wheat soils moist longer. They are doing this in three ways: (a) they plant the wheat late so that the plants don't get so big; (b) they do not use any more fertilizer than necessary to get the yield they wish. The soil stays moist longer, the bacteria are active longer, and the fusarium is suppressed. (c) different varieties vary greatly in the amount of water they use. The varieties now used have a better water economy; the soil stays moist longer, the bacteria are effective longer, and the disease is less troublesome. That is environmental manipulation.

The other type of control, and I think the one Bruce was alluding to, is to treat soil or add antagonistic microorganisms to it in order to accomplish biological control. In the nursery and florist industry this is particularly promising, because you generally are adding single organisms. When you do this it is almost necessary to get rid of organisms already present. It really doesn't matter whether you treat soils with methyl bromide, chloropicrin, or steam. You reduce the population that is there, then add an antagonist to it. This works very effectively under these conditions. But it does not seem to work under field conditions where the soil is not treated to get rid of the existing microorganisms. Single antagonists work well in treated soil, but have not been very practical in field use.

BILL SNYDER: Thank you very much, Ken. I would like to thank the three speakers from Berkeley, Dr. Raabe, Dr. Koehler, and Dr. Baker for coming down here this evening and discussing these three very interesting topics with us.

SQUARELY TOWARD THE FUTURE

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Where is your company headed with respect to profits, costs, and prices? Can you plan for a given profit? Yes, you can!! Planning is a never-ending responsibility and opportunity: determining the company's goals and the organization and people required to attain them. Planning faces you squarely toward the future.

Planning cannot be done in a vacuum. Facts must be available for plans to be made, facts about your business and about the business world that affects your business. Among these facts must be what you expect to be spending for the goods you produce and sell.

Do we want to consider procedures to determine costs? Do we want to consider what 1-gallon plants, peat, containers, etc. cost me and you and you? Do we want to consider standardized costs for the industry? Do we want to consider what to do with the data we have? Many other questions can be raised — but enough!!

For this discussion I intend to cover, first, a general procedure for looking at costs; second, some procedures for estimating costs; and last, some aspects of the use of cost data in pricing decisions.

The Data System. Before going on to a discussion of costs, let's take a look at data. You and I are aware that it costs money to obtain data. *It matters not whether the data are costs of production, inventory, or accounts receivable over 30 days. Therefore, we must decide whether collecting the data is financially worthwhile. Why collect the data? Is it because it's important to be able to pull out and display this information? Is it because we will use it for making decisions? These are two valid reasons, and there are others. We should recognize that the first* reason costs us money without financial return.

How do we decide how much data to collect? This problem can be approached from the viewpoint of refinement of data and focusing upon where cost decisions can be made.

Systematically, in any data collection system we start with rather gross data. Then we refine the data to suit our needs. For example, first estimate of the cost of production is to take the yearly profit and loss statement and allocate costs to the total number of items sold. Certainly this estimate of cost is gross

and inadequate, but it is a method. Then we can break down to species, block or any other desired unit. In this way we are refining our estimate of true cost of production for a given item.

Next, we must determine what meaningful decisions can be made. A decision whether to substitute machines for labor in some operations, for example, requires collection and analysis of data. This would be true when considering replacing people with machines for hauling plants. On the other hand, because a machine cannot replace people for plant pruning, data collection would not be considered for this operation. This does not mean, of course, that we cannot look at the tools used in pruning, the influence of size of planting, various ways to pay labor for the operation, etc.

You and I are aware of the term GIGO: "Garbage in, garbage out." Too often, because of a system's complexity or because of disinterest on the part of those supplying the input numbers, a lot of useless data gets into our system and comes out of it to garble the decision-making process. The simpler the system of getting and properly recording data, the more likely the numbers will be at least precise enough for our purpose. For example, keeping records by blocks may be meaningful, while keeping records by individual beds results in garbled data.

A data system requires collection and computation. First, someone must observe and then record the information — I have six workers, and we each spent 3½ hours pruning junipers. Second, all of the different pieces of information or bits of data must be compiled. During the month of May, 86 hours were spent making 2150 cuttings at a total direct labor cost of $30.10. How often the observations are made, the forms used to record the data, the business machines to be used to compile the data, the persons responsible for recording the data, the persons responsible for compiling the data and the manner in which the data are displayed to you — these are the parts of the system you develop for your own needs. Obviously the more detailed and complex the system, the more people will be involved — and the more people involved, the more likelihood of GIGO. Obviously too, the more complex the data system, the more alarms you install in the system to make certain the output is within tolerance limits.

The Nature of Costs. At the end of each month, or at least at the end of the fiscal year, you receive a profit and loss statement from your accountant. The various expenditures are grouped into three categories: cost of goods sold, cost of selling, and administrative costs or overhead. As we look at each line item, direct production labor, taxes, telephone, etc. we realize

that each item has a relation to level of production. Some items — direct production labor — vary directly with the amount of production. The more we produce, the more we must spend on *this item. Some items would remain the same even if we did* not produce and sell a single plant — taxes and administrative salaries, for example. Also, some items vary partially with the level of production and selling: we pay a basic charge for telephone and electricity but the more we produce, the more use we make of these; thus, the more we must pay for them. We categorize these items of costs as being *variable* (those that vary directly with the amount of production or sales), *fixed* (those that are essential to "keep the doors open" even without sales), or *semi-variable* (those that are partially influenced by amount of production and sales but also are partially essential to keep the doors open).

There is another way of looking at these same financial data. Bergfeld, Earley and Knoblock (1) emphasize planning for profit and separate costs items as *constant, programmed* and *variable* costs. *Constant costs* are the basic business expenditures *necessary to do business. Taxes, top management's* salaries, and insurance are examples. *Programmed costs*, although appearing to be fixed in connection with current operation, are those incurred because management has made a deliberate decision to attain a goal. Examples are costs of developing new product lines and the equipment required to produce them. These costs can be raised or lowered at the discretion of management from one budget period to the next. Programmed costs can be further subdivided into specific (cost associated *with one sector or product) and general (cost to improve the en*tire business such as research departments). *Variable costs* vary directly with volume of production and include materials, direct labor and labor expenses and selling commissions.

The costs of running your modern nursery are complex and varied. Some costs are incurred to increase sales volume. Some costs are incurred to reduce other costs. We realize that profit is not realized until all costs are covered by sales revenue. How available cost data are used in the decisions on pricing and expenditures depends on our approach and appreciation of costs in relation to output.

Methods of Determining Costs. Each of you has had many opportunities to hear and read how others are determining costs. For example, there are the reports by Thomas Pinney, Jr. (2), Earl Robinson, Jr. (3), and Ralph Shugert (4) in Volume 24 of the Proceedings of our Society. Special manuals on specific crops (5, 7) and reference books (6) also have sections on determining costs.

The first approximation of cost of production is to take the yearly P&L statement and determine the cost of the units sold by dividing total cost by total units. Even with factoring to give different size containers their proportionate cost, this estimate is very gross and not very useful.

A refinement of this approximation is for management to allocate cost by some common unit such as fields, blocks, species or container size. The layout of the nursery and the organization will be considerations. If the nursery is laid out in blocks with a manager for each block, then this becomes a reasonable basis because the manager of the block can be charged with the responsibility of data collection. Records can be kept on the use of resources by blocks, and the costs of the units produced in the block can be determined. Managers can expect costs to vary between blocks depending on size, species, form of plant, etc.

Unit costs have been a concern of nursery managers. Many items of cost are dependent on size of the blocks, number of units produced or some other variable. For example, the efficiency of labor in pruning plants, as measured by the number of plants pruned per man hour is dependent upon, among other factors, the shape of the plant, the plant species, the size of the plant, the number of plants in a bed, and the arrangement of the plants in the bed as well as the tools used and the ability of the laborer. Unit costs must reflect these factors, and they become complex to determine. The question to raise is how meaningful the knowledge of unit cost is to management decisions.

In determining production and marketing costs, nursery managers are allocating all of the cost items to the various sizes and types of products produced and sold. The method of allocating constant costs must be determined. And the procedures for determining variable costs must be established and followed. These are the two most worrisome aspects of determining costs, because we often feel uncomfortable with our procedure — we feel we should be able to do it better, simpler and more accurately.

At this point let me interject the thought that if we concentrate more attention on profit, then many of our hangups will disappear. We will look at cost in relation to profit later.

Constant costs are generally allocated to individual products on a space and time basis. The justification behind this is that these costs continue at the same level whatever the size or product and that many of these costs are charged to the business on a space basis — the real estate taxes we pay are on the basis of the size of the area, for example. The size aspect — 1 gallon vs. egg container size for example — is usually factored

or converted to a "common size." One gallon equivalent is a useful concept, where on a space-occupied basis an egg container has 2½ one-gallon equivalents. Thus, each egg container would accumulate 2½ units of constant cost for the same time that a 1-gallon container accumulates 1 unit of constant cost.

Direct variable costs of labor, materials and sales commissions are often computed by taking necessary data off of sales slips, invoices, etc. Total direct labor can be computed from time cards.

Many problems arise when management wants to determine where labor was spent among the numerous jobs needed for the production of plants. Among the alternative procedures for determining this information are: (1) keeping a continuous and detailed time chart on each individual, and (2) using industrial engineering and time and motion procedures to estimate the true time spent at various tasks.

Both procedures are used, depending on the situation. Even when continuous records are kept, management often wants to analyze certain operations in detail, using time and motion techniques, with the objective of eliminating inefficiencies. This holds for production labor, office work, management duties and all aspects of a company's operations.

Cost in Relation to Price. You generally use one of two approaches for pricing products:

(1) You consider that the marketplace establishes the price and go along, even when certain companies are considered to be price leaders.

(2) You price on the basis of "cost-plus," that is, you calculate the cost of production, add on selling and administrative costs, and then add on a profit percentage to establish the selling price.

Market reaction to price is important; you don't have to passively and slavishly accept this price. Within the latitude allowed by market reaction to price you can actively establish price for profit and growth.

The "cost-plus" approach assumes that each unit sold would be contributing a percentage of the sale price as profit (Table 1). Only if the predicted volume is sold will the profit be the same as planned. The income above direct variable costs for the first units sold would contribute towards covering constant and programmed costs (Table 2). Only after the break even point is reached will profit begin to accrue from each unit sold. The percentage of profit will vary with the number of units sold (Figure 1).

Table 1. Cost-plus methods using assumed data to price nursery stock.

	per 1-gallon container
Materials costs	$0.258
Direct labor and expenses	.226
Production overhead	.070
Total production cost (cost of goods sold)	0.554
Selling costs	.129
Administrative costs	.066
Total cost	$0.749
Profit @ 15% of total cost	.112
Selling price	$0.861

Table 2. Cost analysis for the procedure of pricing for profit.

		Percent of Sales
Selling price	$0.861	100
Direct Variable Costs (Vary with volume)		
Material	.258	
Labor	.226	
Selling commission	.083	
Total	$0.567	66
Margin contributed to cover constant and programmed costs and contribute toward profit	$0.294	34

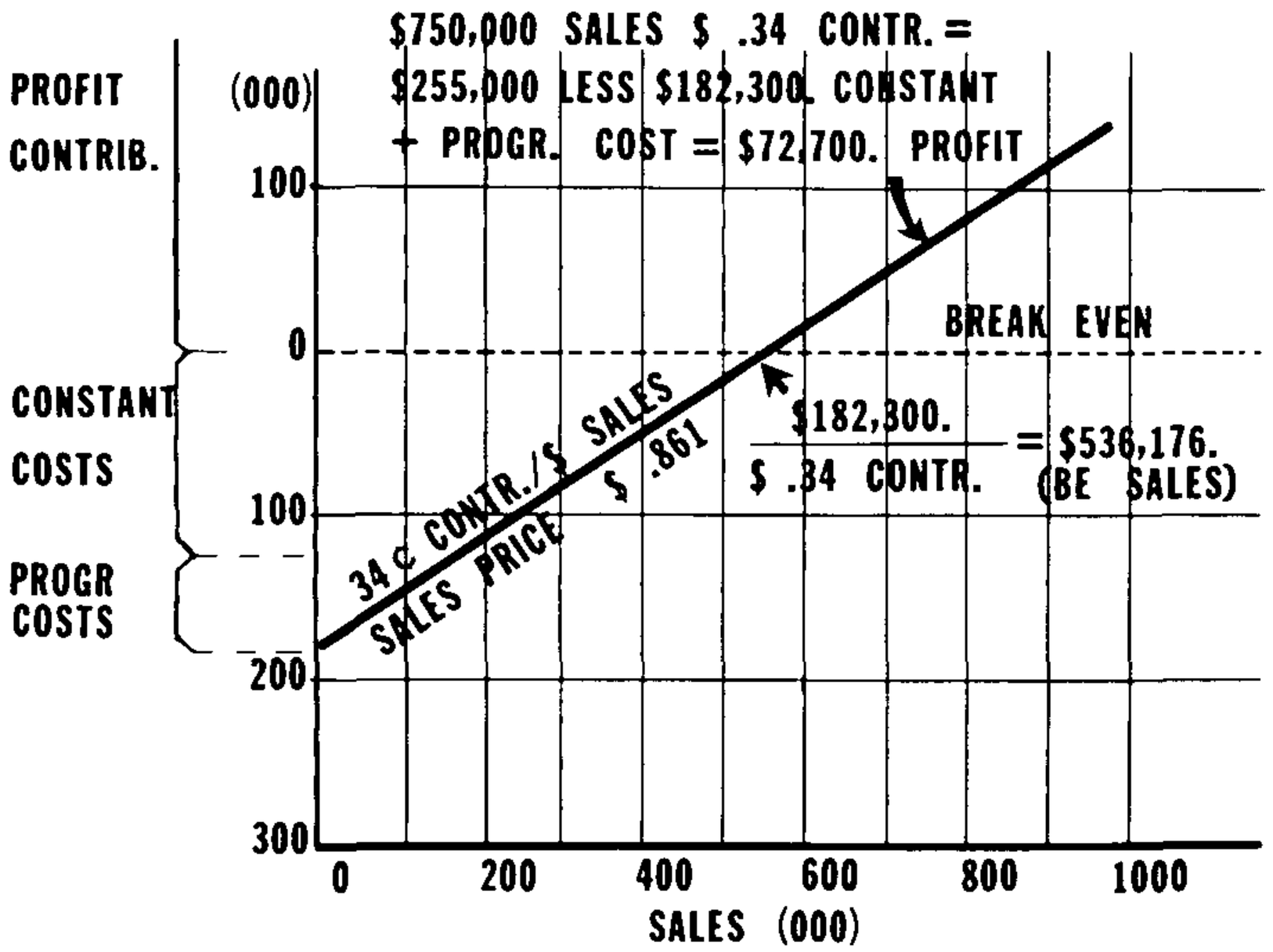

Figure 1. Interrelation of cost, price, volume and profit using data shown in Table 2.

This assumed nursery will require a sales of $536,176 to break even. If its sales totaled $750,000, profit will be $72,700 for a profit of 10.7%.

From this chart (Figure 1), it is evident that the first units sold do not contribute profit to the nursery. Only after 622,532 one-gallon containers are sold at $0.861 each will each additional sale of a one-gallon container contribute profit.

Likewise, it is possible to see that changing the sales price changes the contribution rate (Figure 2). The slope of the revenue line and the break even point change. The number of plants the nursery must sell to gain $72,700 in profit, or 15% profit, changes as well.

By predetermining the dollar profit desired and knowing costs, you can calculate how various prices will influence the *total volume of sales needed to reach the profit goal. Then you* can examine the marketplace and determine the price most likely to allow you to reach your profit goal.

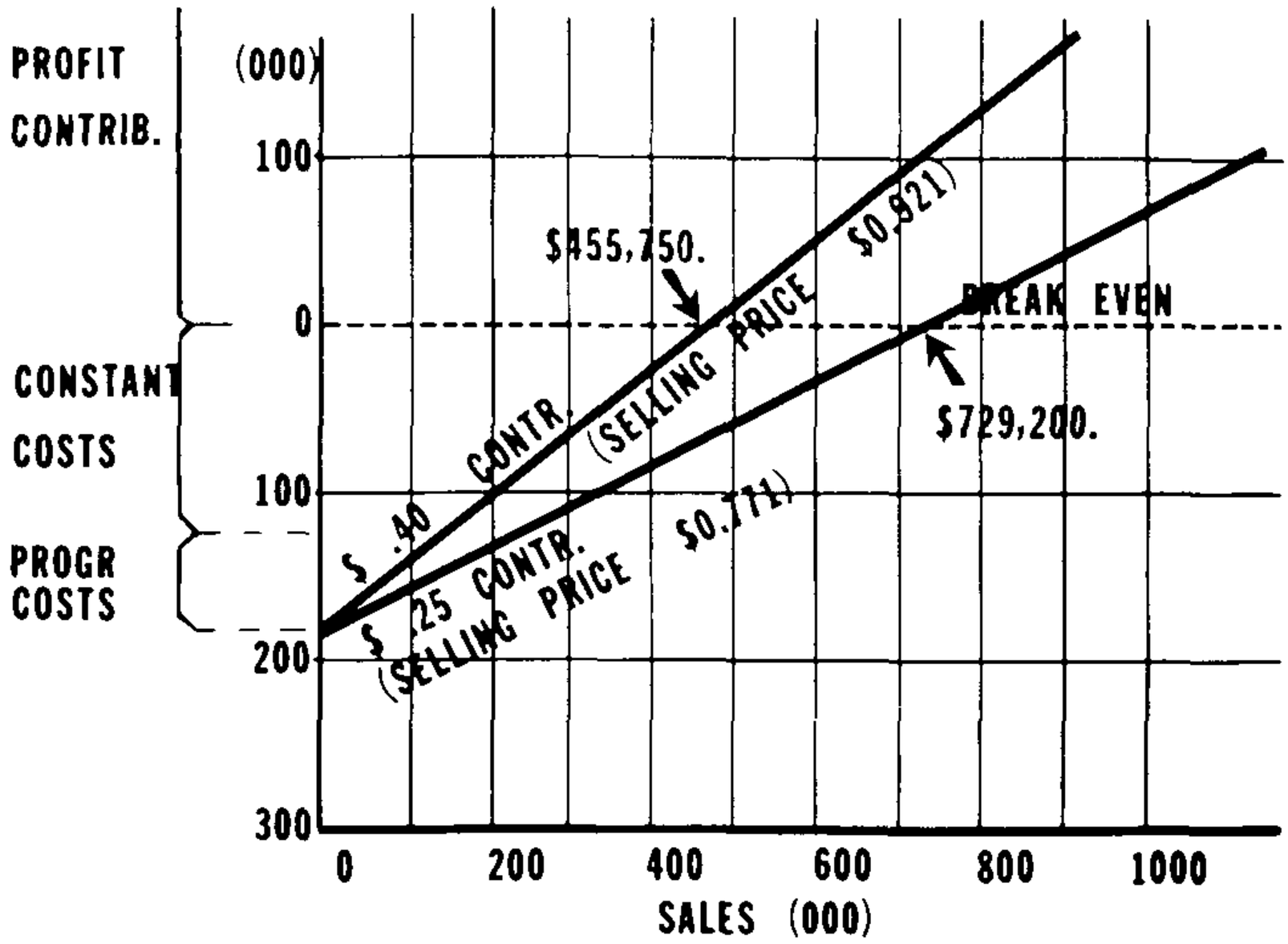

Figure 2. Influence on profit of changing sales price.

This concept of pricing on the basis of direct cost and planned profit is described more fully by Bergfeld, et al. (1), and Lennon (8).

You are Unique. Obviously we want to make our nursery more profitable, and we want to use data to make better decisions. In this regard, we should select the key indicators of performance (KIP) that would immediately tell us when things begin to go bad. We should watch these KIP constantly and

closely. Margin contributed could well be a KIP of value.

In this paper, I have not attempted to give you specific procedures to determine costs. Each of you is unique, and you manage a unique nursery. Thus, you must develop your own procedure to meet your requirements.

Costs and data system you use to determine costs must be related to other activities. Often these other activities — pricing for profit for example — can have a more profound influence than simply knowing costs.

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THE RELATIONSHIP OF JUVENILITY TO PLANT PROPAGATION

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The subject of juvenility in plants is receiving increasing attention from propagators, horticulturists and foresters both from academic interest and practical necessity. A worldwide study group for horticulturists, foresters, and pomologists interested in juvenility has been formed under the auspices of the International Society for Horticultural Science. In 1975, two international symposia were held, one in Beltsville, MD., U.S.A. and one in Berlin, Germany (17)[a].

Most interest in juvenility focuses on 3 significant practical problems. First, how can one maintain or increase the rooting potential and regenerate hard-to-root cultivars by vegetative propagation? Second, how can one shorten the juvenile period to bring about early flowering to speed up breeding programs for fruit, nut and forest crops? Thirdly, how can one avoid (or utilize) the variability in growth performance and morphological appearance that sometimes characterizes juvenile growth

Relationships, such as the effect of juvenility on rootstock behavior, may also be important but are not well understood. Likewise, seed production of forest trees must be conducted to retain the long juvenile period important in this crop.

CONCEPTS OF JUVENILITY IN RELATION TO LIFE CYCLES

Understanding and finding solutions to the above problems for specific plants requires basic understanding of the life cycle of the plant because it is only in this context that juvenility makes sense. Thus, we must distinguish between the life cycle of an individual plant started from seed (Fig. 1) and a life cycle of an individual plant started vegetatively from a bud or a cutting (Fig. 7) (4).

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[a] References are made by number to specific publications; names identify papers in the 1975 Symposia that deal specifically with the subject under discussion.

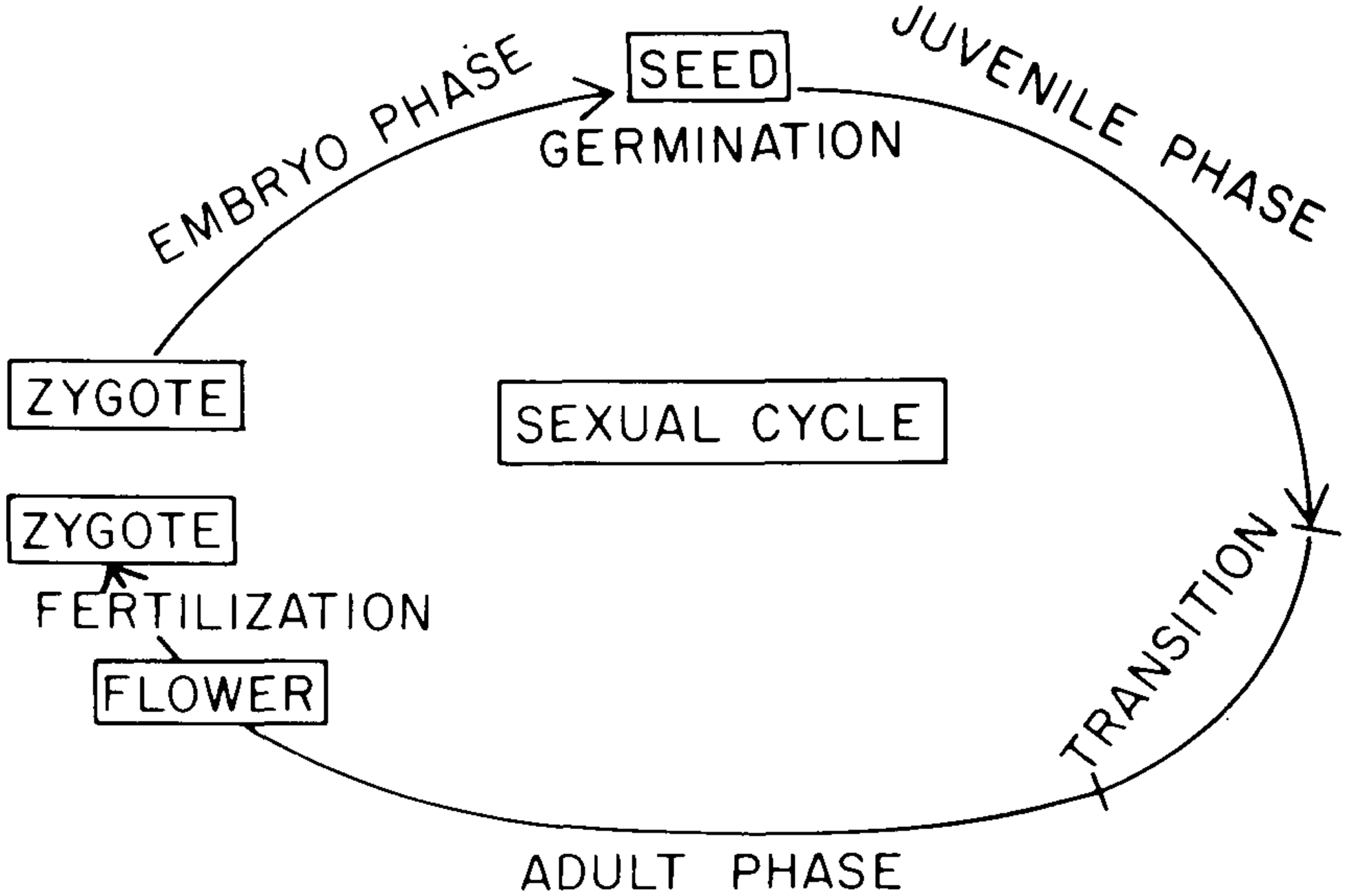

Figure 1. Development cycle of a plant grown from seed. Shows the distinction between the juvenile phase and adult phase.

Seedling life cycles. (Figs. 1 and 2).

1. The cycle begins with a single cell, normally the *zygote*, which is the first cell originating from fertilization of the egg by a sperm cell. (Sometimes, however, the cycle could begin with another cell as in *nucellar embryos* or unreduced sex cells, as in *apomictic embryos*.) This first phase involves growth of the embryo within the mother plant and is terminated by germination of the seed.

2. The growth phase immediately following germination is defined as *juvenile* and is a period of growth in size and volume resulting from cell division in the meristems. It is part of the concept of juvenility that these growing points cannot initiate flower buds at this stage. In some plants unique morphological characters, as thorns, distinct leaf shapes, etc., may be present in the juvenile phase. These may be useful as "markers" to identify changes in phase.

3. A *transitional* phase follows the juvenile phase and involves an internal shift from strictly vegetative to reproductive in which flower buds can be initiated. Sometimes there are abrupt changes in appearance of the plant; in others, the change may be gradual and the time when it begins difficult to identify precisely.

4. Eventually the plant becomes fully reproductive and produces flowers, fruits and disseminates seeds. This is the

adult phase. Production of new seeds repeats the sexual cycle and creates a new generation.

Terminology is important in the context of juvenile to adult changes. It seems desirable to avoid the terms "age" or "aging". Rather the consensus among workers in this field is to use the term "maturation" for the process and to refer to the reproducing plant as "adult" or "mature", rather than "old".

Eventually, the plant becomes senescent and dies. In some cases this follows because growing points produce only flowers and fruits and none are left to regenerate shoots. In an annual, all shoots become flowering in one season and the plant dies thereafter. Some bamboos and some Agave plants may be juvenile for many years — 50 to 100 — then suddenly become reproductive, flower, and die after seeds are produced. Perennial plants continue to live year after year because only some of the shoot buds become reproductive, but other buds remain vegetative (not necessarily juvenile) and continue the existence of the plant.

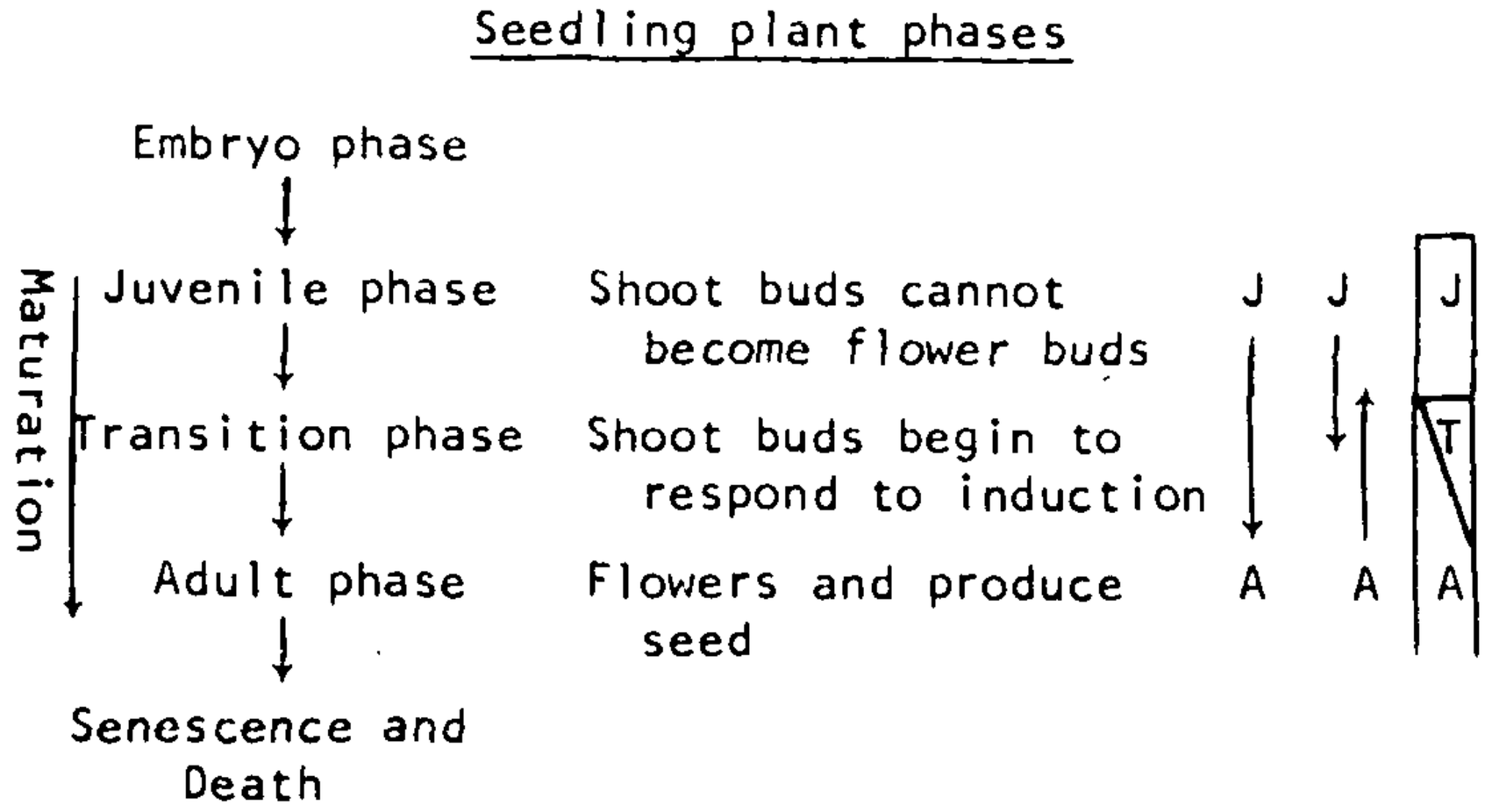

Figure 2. Phase of maturation from juvenile to eventual death. Change may be considered as a gradual shift from juvenile to adult, J → A, 2 distinct overlapping phases, or 3 separate phases — juvenile, transitional and adult.

Juvenility and growth patterns. Plant growth and development proceeds in individual growing points (meristems) in the tips of shoots and roots, and in lateral points in axils of leaves. Some of the cells in these meristems continue to divide to produce new cells and thus continue to expand the plant; others remain behind to become stems, leaves, roots, etc. More and more new growing points are produced at nodes as the plant increases in size and complexity (Borchert, Lord, 17).

With time, these growing points become separated from each other and progress through the maturation phases at different rates. Various research efforts are now being made to establish the relative importance of the internal control system within the growing point itself, the surrounding environment, and the hormonal influence of the nearby leaves, other growing points, and the roots for determining the phase of maturation (Wareing, Hackett, Schwabe 17).

Juvenility is related significantly to propagation in several ways. First, control of maturation from juvenile → adult is largely a function of the development of the growing point. Thus the duration of the juvenile phase is determined by number of cell divisions achieved by the vegetative meristem (and the number of nodes) rather than chronological time. Keeping juvenile plants growing continuously at their maximum rate with optimum growing conditions, e.g., continuous light, long days, adequate nutrition, increased CO_2, etc., — will allow the growing points to literally *grow their way* through the juvenile period in the shortest time and result in early flowering. Aldwinckle (17) brought apple seedlings into flower in the greenhouse in 16 months compared to 3 to 8 years for plants growing in the field. Similarly, Zimmerman (16) found certain (apomictic) crabapples to have a juvenile phase of 75 to 80 nodes irrespective of the time required to attain this height. Similar response from growing seedling plants rapidly in controlled environments have been shown for pear (14), birch (Longman 14), and spruce (Young 17) and the principle is probably universally applicable (Fig. 3). Growth and development has also been stimulated greatly in annuals by environmental controls applied as early in their life cycle as possible (4). Even excised embryos of some peach cultivars respond to long photoperiods and increased temperature (6).

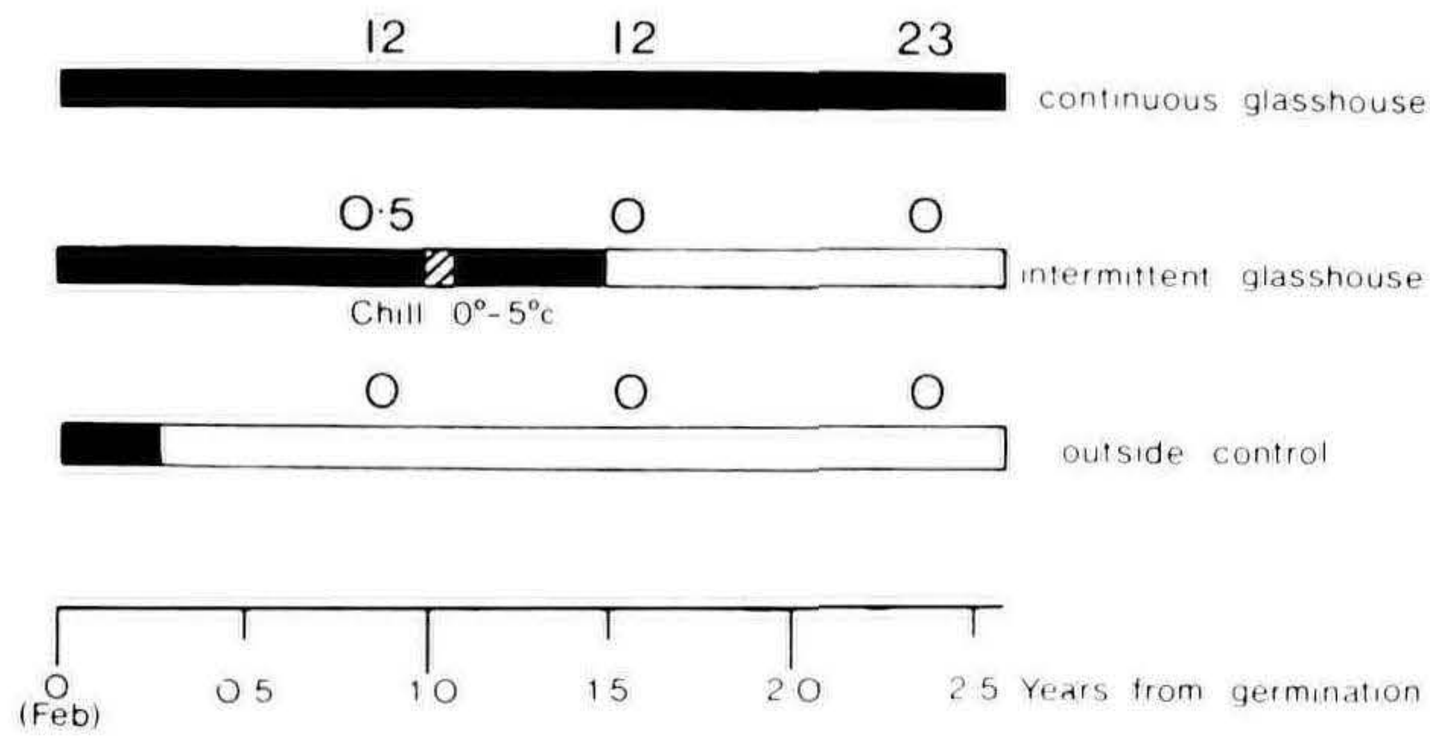

Figure 3. Effect of growing conditions on flowering in *Betula verrucosa seedlings*. *Dark* = heated greenhouse, light = out-of-doors. Numbers refer to mean numbers of catkins per plant. (from Longman, 17).

The second application is that different parts of the plant tend to remain juvenile and others adult, as shown in Fig. 4. This phenomenon has been known in the horticultural literature as *topophysis* (4). It leads to a paradox in terminology in that the oldest part of the plant, from standpoint of chronological age (base), actually remains the youngest in terms of maturation. Likewise, the youngest part in time (top and extremities of branches) may be the oldest in maturation.

Fig. 4 could depict a ten-year-old apple or citrus tree which grows very vigorously, with fruiting only at the top and extremities of the branches. Or it could be a 25 year old pine or spruce tree with cone production very high in the tops of the tree. However, it could also be a tobacco plant of one year duration with lateral shoot buds at the lower nods and flower buds only at the upper nodes. McDaniel and Hsu (17) found that, for a given tobacco plant a certain number of nodes was required to flower. If the nodes were removed as cuttings in consecutive order from base to tip, the cuttings from the base produced new vegetative shoots but the upper ones produced flowers. New shoots required about the same number of nodes to flower as did the original shoot at that node. It can be said that the individual bud "remembered" its position and continued to express the potential for that position even when separated from the original seedling plant.

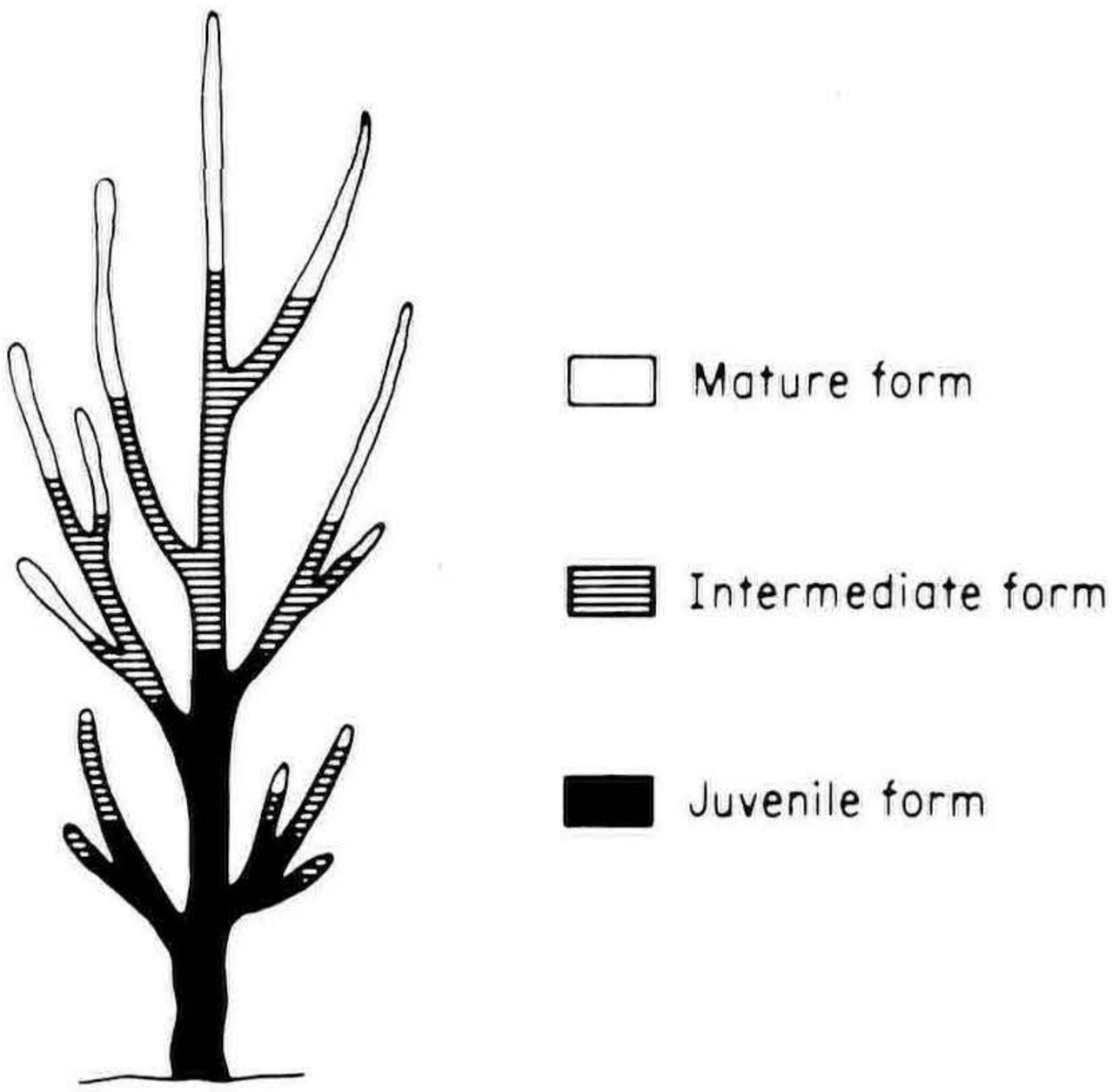

Figure 4. Variations in location of different maturation phases on a mature seedling plant.

Fig. 5 shows variations in three important characteristics: rooting potential, flowering, and shoot vigor associated with juvenility (Borchert, 17). The level of maturation is indicated in the top of the graph by change in leaf characteristics as "markers". In this sense "age" (maturity) must be identified as number of nodes or cell division.

For plants, such as many woody trees, e.g., conifers, etc., the rooting potential may drop sharply with maturation (A). Other species and individual seedlings, however, may show the pattern of A^1 which indicates that significant rooting potential is retained in the adult phase, providing that appropriate propagation procedures are followed. Most plants probably fall between these extremes. Ability to initiate flowers marks the termination of the juvenile state (B) but there may be plant species or cultivars where the distinction can not be so sharply defined (B^1). Likewise more vigorous growth is associated with the juvenile phase (C). In some plants the difference in growth habit may be very striking — those propagated vegetatively from the adult phase may be bushy and with much lateral branching whereas those from juvenile tissue grow upright with a central leader.

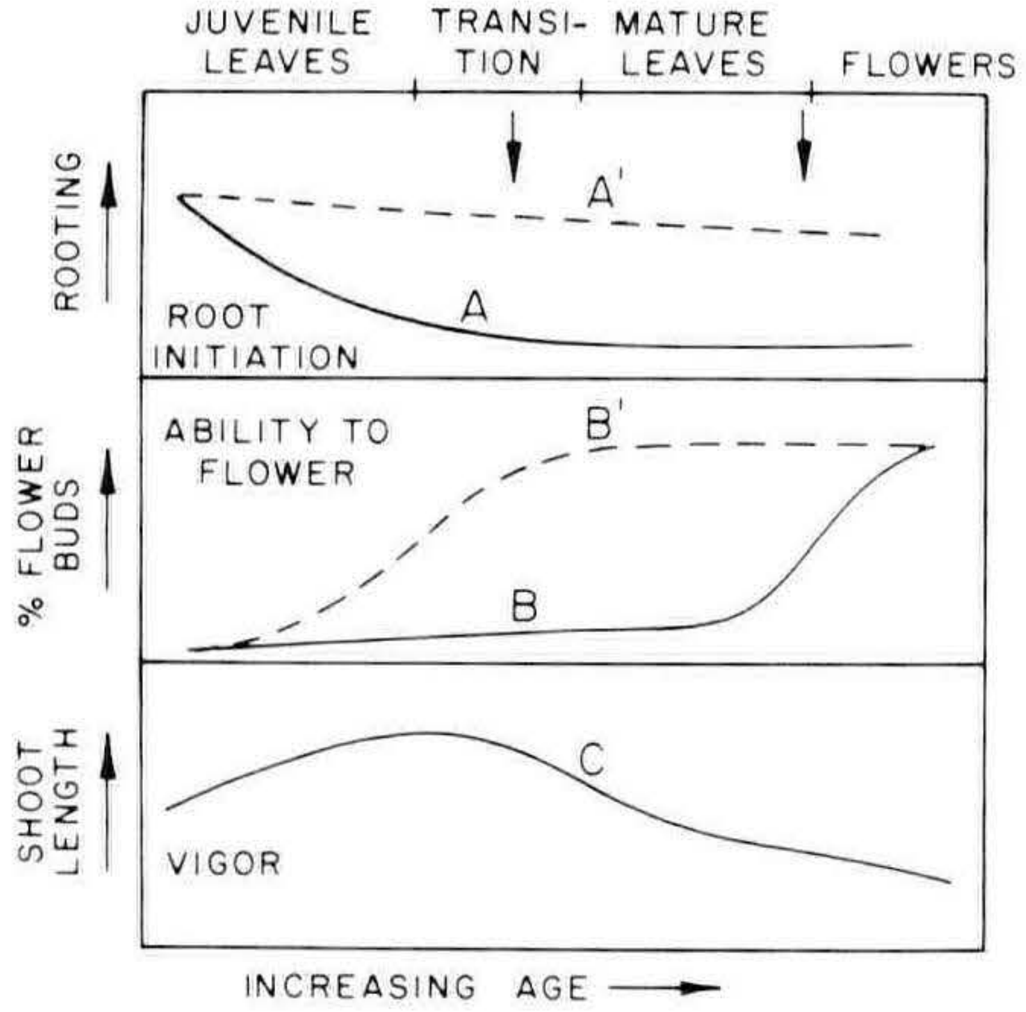

Figure 5. Changes in potential for *rooting*, *flowering* and *vigor*, in relation to maturation are measured here as node number, not as chronological age. Leaf morphology (top of graph) is used as a "marker" to indicate phase change. Arrows indicate when significant changes had occurred. (See text for further explanation).

Juvenility and evolution. If one considers that a distinct juvenile period has value to a plant in nature, one can understand why various juvenile characters exist. Consider the following examples:

a. In the crowded forest environment, it is a distinct advantage, if not a necessity, for a tree to have initially strong, upright, vigorous growth without flowering in order to compete with its neighbors for light.

b. It is a distinct advantage to be able to regenerate or resprout from near the base of the plant to permit survival after fire or browsing animals.

c. It would be a distinct advantage to have thorns (apple, pear, citrus), scale-like (junipers, etc.) or spiny (holly) leaves to ward off browsing animals in the forest.

d. It would be a distinct advantage for a plant in the midst of a dense jungle or forest, to be a vine, grow along the ground until it reaches a stake or tree, grow upward, twine around the support until it reaches the top where it reaches sun and air. Note the *Hedera helix* (Fig. 6).

Numerous other examples could be cited but all underscore the evolutionary advantage of juvenile characters in which the plant not only has such morphological characteristics but also has the flexibility to produce them when needed and shut them off when not.

In the dogma of modern genetics, the basic control mechanism of the cell resides in the DNA molecules of the chromosomes. These molecules are the same for all cells in the plant. However, the information utilized from such basic molecules differs in different development stages and in different organs of the same plant. At this time our understanding of gene regulation in higher plants is very limited.

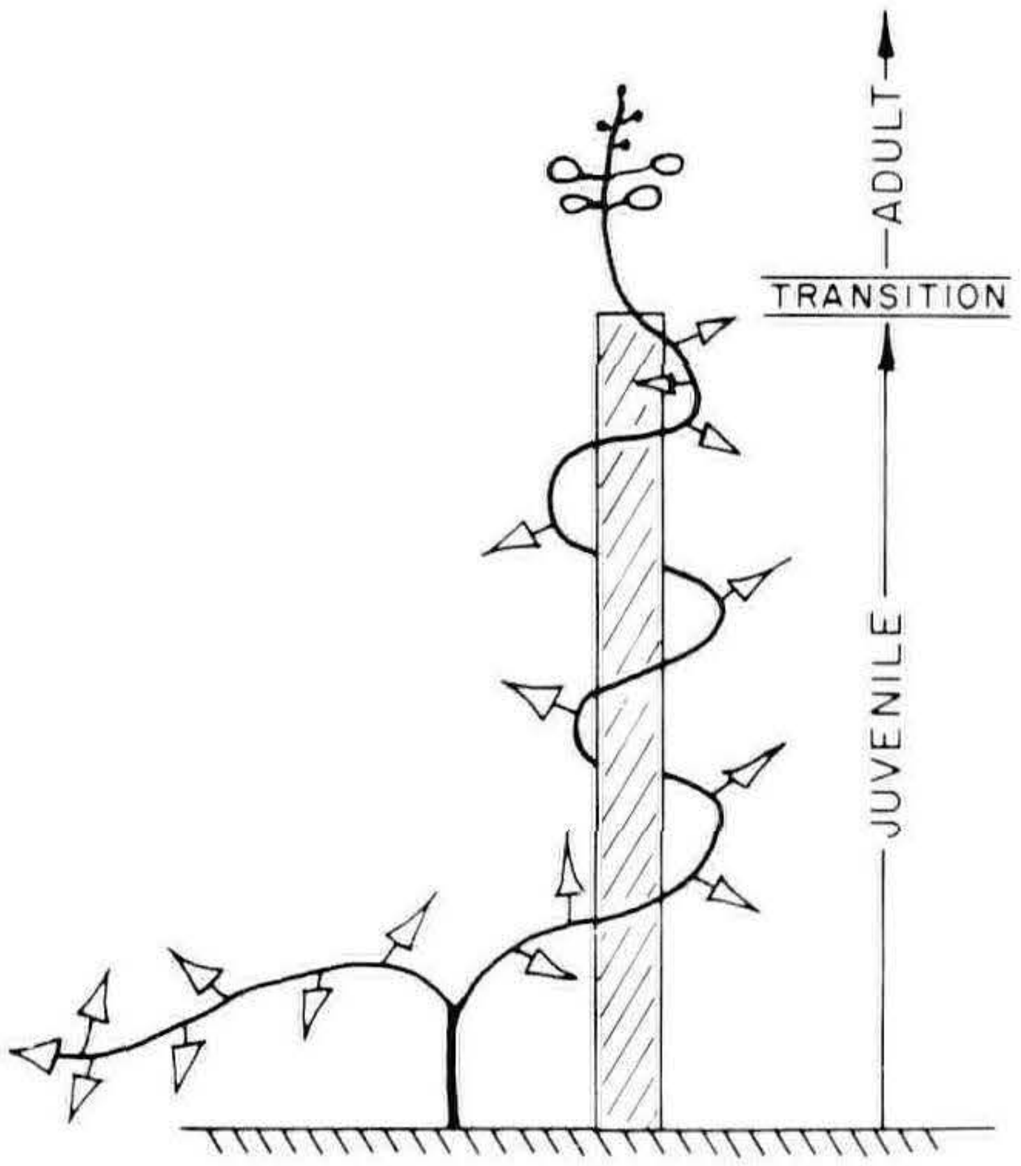

Figure 6. Diagram of an ivy plant (*Hedera*) showing how phase change may be correlated with growth habit.

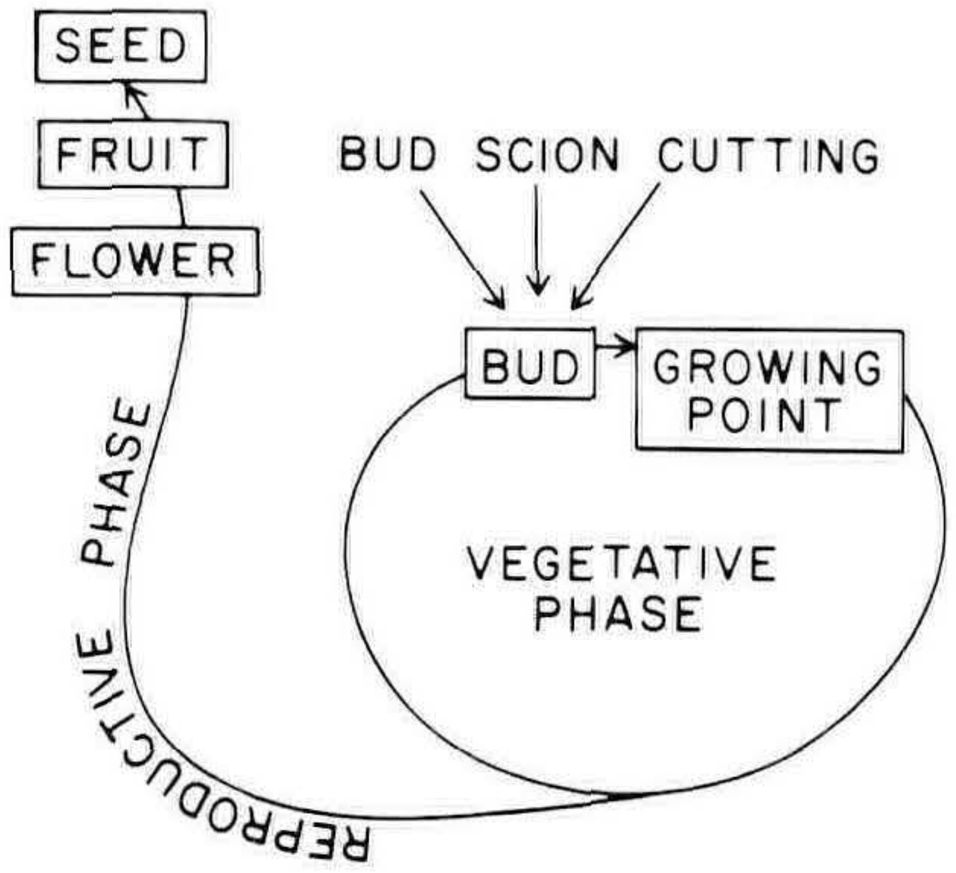

Figure 7. Growth cycle of a vegetatively propagated plant in the "adult" phase. Many growing points remain vegetative (not juvenile) and maintain the plant as a perennial. Others become reproductive, become flowers, fruits, and then die.

The vegetative life cqcle. Consider now the vegetative — reproductive life cycle of the plant shown in Fig. 7. Such a plant may start as a bud or a cutting removed from any part of a seedling plant as shown in Fig. 8. The plant could be grown on its own roots, as in a cutting; or as a scion grafted to a rootstock which, in turn, could either be a seedling or an own-rooted cutting. Continued vegetative propagation produces a group of plants referred to as a *clone* and which could become a named *cultivar*. Since control of juvenility is in the growing point, the new plant could start either as juvenile or adult depending on source of the bud or tissue. Plants propagated vegetatively from juvenile tissue show juvenile characteristics and buds and cuttings derived from mature plants retain those characteristics.

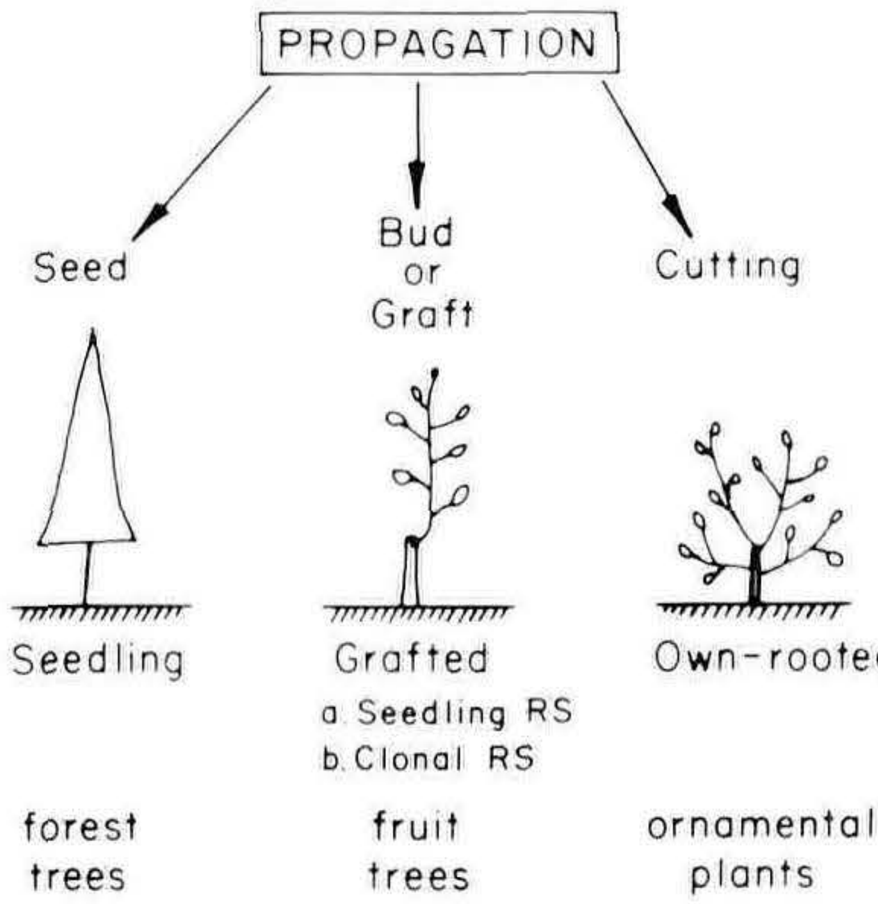

Figure 8. Different forms of plants may be produced depending upon whether they are propagated by seed or are vegetatively propagated.

The growth cycle of the vegetatively propagated adult plant, therefore, is fundamentally different from the seedling cycle (Fig. 9). Two phases are recognized — a vegetative phase and a reproductive phase. In the vegetative phase, shoot tips may resemble those in the juvenile phase (at least superficially) but can now respond physiologically to flower-inducing stimuli. A certain amount of elapsed time and a certain amount of growth may be needed before flowering is initiated. Many of the horticultural practices, such as chemical regulation, grafting to dwarfing stocks, girdling, growth reduction, etc., are effective in inducing initiation of flowering. In contrast to their effect in the juvenile phase, environmental and management conditions that produce excessive vigor, such as high nitrogen, heavy pruning, etc., may delay flowering and fruiting. These are the opposite conditions that are effective in promoting the juvenile phase to induce flowering.

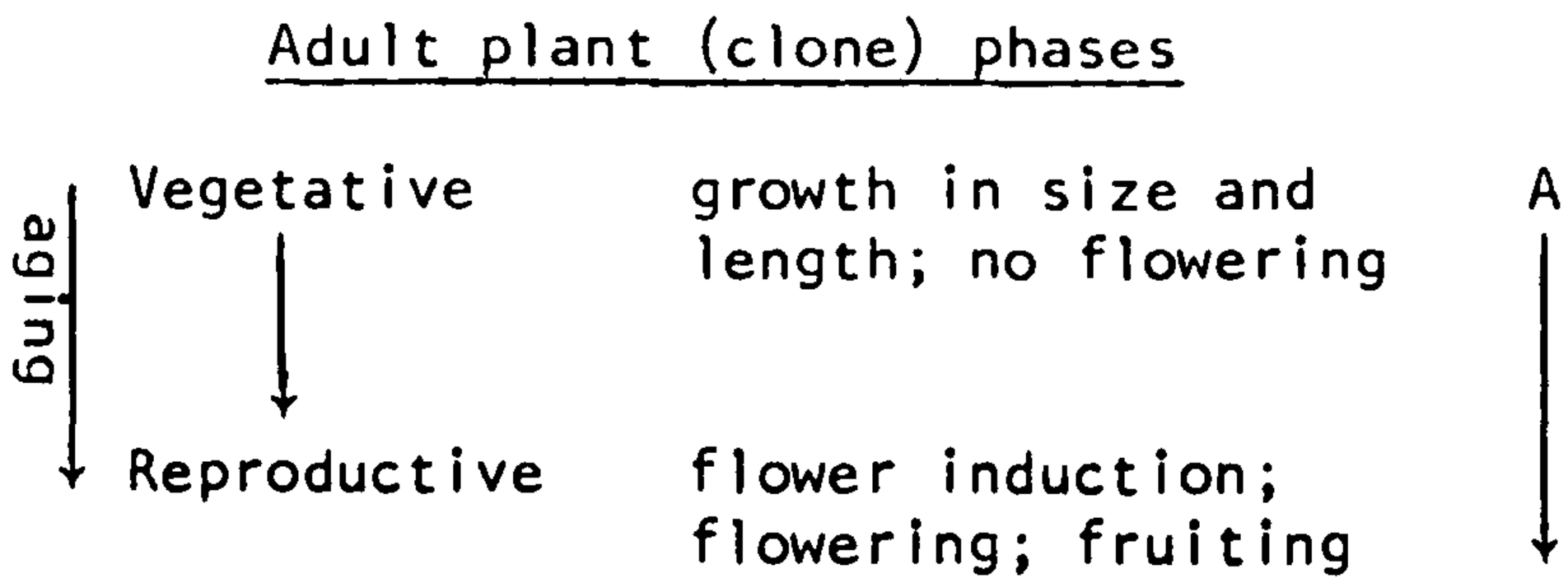

Figure 9. *Phases of development of a vegetatively propagated clone in an* adult phase. The process of change may be referred to as "aging" rather than "maturation", as shown in Fig. 2.

Probably most fruit tree growers have never seen a juvenile fruit tree since all grafted cultivars are in the adult phase. Whether or not vegetatively propagated nursery stock is juvenile or mature would depend on what growth form was selected in the initial development of that material.

Both the specific character associated with juvenility and the cellular control mechanism that controls the timing appears to be genetically controlled and inherited. Fruit tree cultivars that bear precociously tend to produce seedling offspring with short juvenile periods (Visser 17). Ease-of-rooting is inherited and varies greatly within seedling populations and may not be dependent on being in the juvenile phase.

Melchoir (17) found that in seedling populations of *Chamaecyparis pisifera* various foliage types associated with the juvenile phase was inherited but the time when these leaf characters changed was not necessarily related to the time of flowering. In some plants, the character and the timing may be independent of each other; in others they may be associated.

JUVENILITY AND REGENERATION BY CUTTINGS

The fact that cuttings from juvenile plant material initiate adventitious roots and shoots more readily than adult or mature material is well known. Our concern is to utilize this principle in propagating potential cultivars either as own-rooted plants or as rootstocks, which as adult material are difficult to propagate vegetatively.

1. **Selection of juvenile material.** Juvenile shoots may arise from the base of mature plants, appearing as watersprouts, or suckers from the roots or near the surface of the ground at the root/stem junction. Such material has been rooted successfully in such species as chestnuts (Vietez, 17), oaks (Morgan, 17), eucalyptus (3), black walnuts (2), and pecans (8), among others. However, if this procedure is to be of practical value, one must be able to continue to produce such juvenile material of selected clones in quantity sufficient to meet commercial needs. This means some method of maintenance in a stock block or some other procedure must be used to preserve the necessary rooting potential.

2. **Hedging and heavy pruning of stock plants.** This procedure would appear to be an essential part of a program dependent on utilizing juvenile material. Otherwise the natural tendency toward maturation may result in the loss of rooting potential. Whether or not heavy pruning and hedging involves rejuvenation to the juvenile phase or simply the stimulation of vegetative shoots to a condition more favorable to rooting, is difficult to answer. Stool beds have been cited as an example of induced juvenility, although the rejuvenating influence of this treatment may vary with the cultivar. What is essential is that the rooting potential be stabilized at a required level.

Hedging for propagation materials has important uses in forestry, as in Monterey pine (Libby 17) and other forest trees. Work with olive provides another example (12), where better rooting potential comes from basal shoots on stock plants.

The program for fruit tree rootstock development and associated propagation systems at the East Malling Research Station, England provides another example where hedging plays a key role (personal communication). New potential rootstocks

originate as seedling plants, grow first in the greenhouse and then are transplanted to the nursery six inches apart where they remain for two years. (Note that close spacing and attending slow growth tend to retain the juvenile phase). After preliminary screening, seedling selections are transplanted to a hedge row, planted 1 to 1 1/2 feet apart, and cut to a height of 1 1/2 to 2 feet. Propagation tests for ease of rooting are then made on this material and, within the group of plants selected for propagation potential, rootstock tests are conducted. Again, it may be an academic question whether this process involves selection of individual easy-to-root clones completely independent of the juvenile phase, or whether the process involves a stabilization of juvenile phase. Nevertheless, the point is that the selection for ease of propagation precedes selection for horticultural characteristics.

3. **Reversion or reinduction of the juvenile phase from adult material.**

a. *Initiation of adventitious shoots on roots or sphaeoblasts.* Shoots arising adventitiously on roots or stems (sphaeroblasts) are characteristically juvenile in appearance and can often be rooted easily. Schwabe (17) reported that he and students had developed roots on a few cuttings of hard-to-root, adult 'Lord Lamborne' apple; these produced a continuous supply of adventitious shoots which could then be detached and rooted. Although such plants were juvenile in appearance and rooted readily, they flowered within 2 years and would respond readily to flower-inducing treatments. The possibility that one can separate the genetic control of flowering and rooting in the same clone, as these results suggest, offers exciting possibilities for future work.

b. *Reversion through applied chemicals.* The fact that biochemical differences can be measured between juvenile and adult material has been shown by numerous investigators. For instance, the existence of rooting co-factors in conjunction with auxin has been demonstrated on juvenile material (Heuser, 17). Gibberellins and perhaps other growth promoting substances, as auxins, have been associated with juvenile growth whereas growth inhibiting substances, as abscisic acid, and other naturally occurring inhibitors have been associated with the adult phase. In such cases, it is not certain whether their presence are causes or effects.

Nevertheless, it has been possible to rejuvenate adult ivy (*Hedera*) with gibberellic acid (Hackett, 17). Furthermore, this reversion can be prevented by abscisic acid. GA applied to pear, citrus, acacia and some *Prunus* species can produce thorny, vigorous juvenile-like growth but it is uncertain if actual rever-

sion occurred because no repropagation tests were made. On the other hand, early flowering has been induced in mango by ethephon, an effect that was reversed by GA (Chacko, 17). To further confuse the issue, applications of GA to many conifer species will produce cones (female flowers). This latter discovery appears to have significant application to seed production practices in forest trees (Pharis, *et al.* 17).

One of the potentially significant developments reported at Beltsville, (Wardell, 17) and since published (15) involved experiments in which extracts shown to contain DNA from the flowering adult phase of a tobacco plant were injected into another tobacco plant and produced flowering. Extracts of a plant in the juvenile phase failed to do so. One of the essential aspects of the experiment was that foliage of the juvenile portion had to be removed before the extract would be effective. The implications of these findings are that the control of the maturation phases may indeed be located in chromosomes at the informational sites of the DNA molecules, and procedures could be developed to program or deprogram plants to whatever phase one wanted. Further the foliage is shown to have a controlling influence and the relative amounts of each may have to be evaluated. Future experiments will determine the validity of these implications.

c. *Grafting effects.* A third way by which reversion has been produced is by grafting. However, results have been so conflicting with different plants that at present it is impossible to establish definite principles. Grafting scions of seedling plants to dwarfing precocious rootstocks can sometimes stimulate flower induction but the scions must have reached a particular stage of maturation before this happens. There is a possibility, however, that the juvenile foliage has an inhibiting effect on flowering and must be removed.

On the other hand, these are indications that reversion of mature scions is possible. For example, grafting adult ivy scions to juvenile stocks has produced reversion in new shoots (Hackett, 17), providing the temperature was sufficiently high. Seedling rootstocks often invigorate scion cultivars grafted to them whereas clonal rootstocks may be dwarfing and induce precocity. Monselise has shown with nucellar seedling material in citrus that this invigorating effect can be attributed to a juvenility influence (10). More directly applicable to propagators is the situation in rubber (*Hevea brasiliensis*); rooting of mature clones has been enhanced by grafting to juvenile plants (11). Success of developing easy-to-root clones of eucalyptus and limbe has recently been reported by grafting of mature shoots to juvenile seedling stocks (7).

4. **Tissue culture, micropropagation and juvenility.** Many species of herbaceous plants are now being propagated successfully by tissue culture and shoot-tip culture. Successful propagation of woody species in *vitro* is more difficult and has been achieved in relatively few species, such as, easy-to-root clones of aspen (14). Selecting juvenile tissue may be important, if not essential for success of this material.

The two methods — tissue culture and shoot tip culture — are fundamentally different in that in tissue cultures completely new adventitious shoots, roots, or small embryos (embryoids) are produced from callus. In micropropagation with shoot tips, growth takes place from meristems and axillary buds which are already present, although sometimes adventitious shoots may also arise in the process. Thus, these shoot tips can retain either the juvenile or adult phase depending upon the source of explant. On the other hand, the possibility exists that the adventitious shoots and embryos regenerated through tissue culture may be juvenile. Whether or not such juvenile material would be horticulturally useful would depend on the needs of the propagator and the use of the plants.

Explants of juvenile tissue (embryos, seeds, nucellus) have been used to achieve regeneration of shoots in tissue cultures in almond (9), apple (1), and *Acacia koa* (13). Abbott and Whiteley cultured juvenile shoot tips of germinating apple seedlings and produced basal callus and *both* axillary and adventitious meristems. Shoot tips from greenhouse-grown adult apple cultivars, on the other hand, produced basal callus and *only* axillary meristems; the number of shoots was less than from juvenile material. Success with non-juvenile material may require the addition to the medium of certain naturally occurring materials, such as phloridzin, or related compounds, as phloroglucinol, as reported by Jones (5) for apple shoot tips. In all cases, the process of propagation is a 2-stage affair, first, the shoots are initiated (whether axillary or adventitious) and secondly, these are removed and rooted.

The juvenile and adult phases apparently are present in certain tissue cultures, as ivy (Hackett, 17). This is significant for basic studies. The possibility of controlled modifications of phases *in vitro* is suggested in a report of propagation of certain early flowering birch seedling by tissue culture (Hubtinen, 17). Seedlings produced by breeding several generations of early flowering birch plants were apparently so precocious and adult that all buds became flowering and none remained vegetative to maintain the normally perennial nature of the plant; vegetative propagation was impossible. However, tissue cultures regenerated plantlets readily. However, when grown to flowering, the regenerated plants had apparently re-established the perennial

habit. The ability to produce vegetative shoots was regained and the excessive flowering tendency was reduced. This suggests that the juvenile → adult changes may be reversible under particular conditions of tissue culture.

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EUCALYPTUS PRODUCTION TECHNIQUES

BARRIE COATE

Barrie's Trees and Shrubs, Inc.
2800 Pleasant Valley Road, Aptos, California 95003

Procedures which we use to produce what we feel are some of the highest quality eucalyptus trees grown in containers are as follows:

The first step is to obtain the highest possible quality fresh seed, wherever possible from isolated seed trees of superior characteristics for a given species.

The second step is to plant the seeds in rows 1″ apart in screen-bottomed seed flats filled with a mixture of 30% coarse peat moss and 70% coarse perlite — from mid-February through June. After the seed is sown, it is covered with fine screened sand to provide a dry, open medium around the germinating seeds. Germinating requires one to two weeks.

These screen-bottomed flats provide a labor-free root pruning when the root-tip gets to the open air, thus encouraging many lateral roots, which do not require much root pruning during transplanting to liners.

They are standard 18″ × 18″ × 2″ wood flats with no bottom boards. We attach ⅛″ galvanized hardware cloth to them to form a bottom, with 1″ × 1″ pieces along two sides to hold the flat off the bench.

Since such a branched root system exists at this point there is little transplant shock and no root binding as they go into 2⅛ × 3⅛″ Fertil-Pots, 3 to 4 weeks later.

The peat moss-wood fibre Fertil-Pots allow a narrow, deep root system consistent with the needs of most tree species at this stage.

The next transplanting into 1 gallon containers is done 3 to 4 weeks later, as soon as a thorough root system shows through the side of the pots. The plants would be from one to two inches tall at that time.

Our next step is into 5 gallon containers in another 4 to 12 weeks, depending on our needs. These 5 gallons, which were seeded in February or March will be saleable, 6 foot trees, with a solid root system and ⅝″-¾″ caliper by October or November.

We find the best response, in every stage, from transplanting plants which have vigorous, young, actively growing root systems. We cull out the genetically inferior individuals vigorously at every stage. We feel this results in economy in not trying to maintain plants which will not be of top quality later on.

FERN PROPAGATION

HILDEGARD SANDER

Route 2, Box 425
La Honda, California 94020

Although it seems easier to understand the life cycle of a flowering plant, it is most fascinating to observe, to learn, and to understand the life cycle of a fern. If I plant 10,000 seeds I can expect 7 to 9 thousand seedlings. If I plant the same number of spores I will feel quite happy to count later 2 to 3 thousand sporophytes.

What is the difference between a spore and a seed? A seed is an embryo (a fertilized egg) surrounded by nutritious tissue which will feed the embryo, and a capsule to protect the embryo. A spore is an asexual cell, unfertilized (no embryo) and containing no nutritious tissue. A seed grows immediately into a plant under the right circumstances. A spore, being asexual, will have to be placed under very exact conditions to develop first into a "stage in between", called the prothallium. Proper conditions are: the right amount of water, light, and a certain temperature. Without these three elements spores may remain dormant but keeping their capacity for germination for many years.

My way of sowing spores is to use a combination of many ideas from other propagators but, more important, I have learned the proper techniques through mistakes, often not well understood.

Because I am growing ferns for commercial reasons I am using, as a medium, a combination of peat, vermiculite, and sand: 2/1/1, with a pH of 5.8 to 6.0.The medium is steamed for 30 min. at 140°F. No fertilizer is used. As a container I am using a plastic tray in which I place an inch of the soil mixture. I mist it quite heavily with distilled water. Then I plant the spores as evenly as possible. Sporing too lightly could mean that later the individual prothallia (intermediate stage) are so far apart that no fertilization can take place; too heavy sporing means that the prothallia will be too crowded and various fungi will have a better chance to develop faster than the spores. Then I cover the tray with glass and keep it a temperature of 60° to 65°F under no more light than 500 foot-candles. In 6 to 40 days after sporing, depending on the type of fern, the soil surface becomes greenish. *Pteris tremula* starts in 4 days, *Adiantum cuneatum* in 10 days, while *Asplenium nidus* starts in 40 to 50 days.

Three to six months later I begin transplanting using the

same soil mixture with no fertilizer and no fungus preventatives, since I will be adding liquid fertilizer every two weeks. During the next three to six months the prothallia produce individual, but still clustered, sporophytes which I then transplant into the 96 cell units in which the ferns are sold.

My technique is to treat the prothallia as little as possible. I am not using any disease preventatives, except that the plastic trays are dipped into 5% Clorox solution in order to be able to use them again.

The biggest production problem is the small white larvae of the fungus gnat. My spore area is relatively small, away from the nursery and other plants, and still quantities of fungus gnats seem to appear overnight. In the spore container I am using lindane powder, ½ teaspooon per gallon of water, and treat only the infected area. Later in the saleable containers I use Diazinon wettable powder at only ½ the recommended strength. I found out that it is best always to use only half of any recommended concentrations in propagating ferns.

A major problem I have to fight is botrytis — the grey mold. Green or black algae are additional problems. Both seem to grow best under similar circumstances: a combination of too high a temperature and too high humidity. In both cases the same treatment works best for me, a mixture of ¼ teaspoon BanRot and ½ teaspoon of Konsan to 1 gallon of water.

CONTAINER-GROWN RHODODENDRONS

ROBERT M. BODDY

Descanso Nurseries
Fort Bragg, California 95437

Container growing of rhododendrons on the northern California coast is nearly identical to conventional California nursery operations in southern and northern California interior valleys. At Fort Bragg, however, we have very cool summers, and therein lies the key element of our effort to produce a commercial crop of container-grown rhododendrons.

In addition to cool summers, winters are relatively mild. Minimum temperatures drop to about 22°F., and we have occasional snow flurries, but neither the cold nor the snow is really severe or long lasting. Thus we do not have the problems of Eastern growers of container plants in having to provide winter protection. And the cool summers are certainly an advantage,

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almost to the point of being an absolute requirement. We have attempted to grow container rhododendrons in southern California, but experienced nothing but trouble from the warm sun burning the foliage, to extensive infections of root fungus diseases caused by excessively warm soil in the containers.

We are also fortunate in having good quality, low pH water for irrigation. So, at Fort Bragg we have many natural benefits and attempt to take advantage of them to the best of our ability. The difficulties we experience are generally created by errors we have made.

Sizes and grading. We produce approximately 30,000 rhododendrons per years. This classifies us as a small grower. Our market is exclusively California. Sizes of plants we offer are in 1, 2, 5, and 12 gallon containers. Over half of the plants we grow are sold in the one gallon size, the balance about equally divided among the other three sizes.

We do not grade our plants by inches of head size or by vertical height. This may cause confusion to those familiar with measurement by inches, but in that our customers have been trained for decades by some of the largest nurseries to buy by container sizes, we do not have a problem of identification.

Cultivar list. We do not offer all of the cultivars we grow, approximately 40, in all sizes of containers. Some plants are sold exclusively in one gallons, the others in larger sizes. The reason for this is that not all cultivars develop equally well for us. Initially, our plan was to offer a large selection of flower-budded two gallon plants. We tried for years with selections ranging up to 20 cultivars. Today, we are only confident of perhaps three cultivars, and offer up to seven. Twelve gallon containers present a similar problem. In years past, we simply shifted up unsold plants. We eventually recognized that a specimen plant, or twelve gallon, had to have a special look. And this was not obtained simply by grooming. The plant had to grow a certain way, bloom at a certain time, and be attractive the year round with outstanding, heavy foliage. Our list of five gallons, which we are constantly changing, is comprised of those plants that perform best for us in five gallon containers.

We would like to offer everything on everyone's list including all of the show winners, but we are simply not able to bring this about. The two gallon plants we grow must flower bud within three years, the five gallons within four years. And there is also a ratio of colors we attempt to maintain: more reds than pinks, and fewer whites than lavenders, blues, purples, and yellows. Blooming dates are important, too, in selecting cultivars for growing. It is better to have most of our list bloom "in season" than very early or very late. So getting all of the require-

ments under control and managed is a very important part of our growing procedure.

Growing areas. We grow our plants under lath and in the open. All of our growing areas are covered with several inches of 3/4" gravel. Irrigation is overhead, though we are gradually installing an emitter irrigation system which is more satisfactory. Our outdoor beds measure 100' by 12', and will hold 400 five-gallon size plants or 896 two-gallons. Sprinklers are Rainbird #20's; five heads will water two beds. Our four lathhouses measure 96' by 144' each, and will hold 30,000 one gallons. Rainjet heads are are used for overhead watering. A Smith injector 1:200 is installed in our irrigation system, and used for both liquid feeding and pest control work. A smaller 1:100 portable Smith injector is used for spot pest control work.

Canning. Potting and canning are done by hand, using no canning machines. We use tractors, trailers, and carts to haul plants, but with our present limited production we have not developed a system to handle more than 500 five-gallon plants per day.

Soil mixing. Soil mixing is accomplished on an asphalt slab using a rototiller for mixing and blending, and a front loader tractor for piling and moving the ingredients. Our standard batch of mix contains 8 cu. yd. This will last us for about one week, and works out well because this is about the time limit we can store the blend without it getting too warm.

After many experiments with materials we decided on a blend of fir bark, peat moss, and perlite. We do change proportions of these materials from time to time as our fir bark supplier continually changes the specifications of the grade of material he delivers. Fir bark in our area is a by-product and availability depends on either the number of housing starts or the demand for redwood lumber. Materials we have used in the past and which proved disastrous include redwood shavings, sand, bark treated with ammonia, and raw redwood sawdust.

Materials we add to the 8 cu. yd. mix include single superphosphate, dolomite lime, calcium carbonate, gypsum, potassium nitrate, I.B.D.U., packaged trace elements, G.U. 49, and calcium nitrate. Changes in the quantities of materials are made from time to time as recommended by a soil testing laboratory. This basic mix and additives are used for all of the material we grow: pieris, mahonias, nandinas, ferns and lithospermum.

Pest Control. Pest control work is primarily preventative. For sucking insects, we inject Cygon into our irrigation system and overhead all of the plants. For weevil control, we inject Lindane into our system and overhead the plants. Slugs and snails are controlled by applying metaldehyde crystals with a

broadcast spreader. We hand spray with a pressure rig for fungus control using various materials: Captan, Daconil 2787, Dithane Z 78, and Benlate. Recently we have commenced using a new material — Dipel — for control of caterpillars and worms. For serious root fungus diseases, we drench with liquid Truban applied through a Smith injector 1:100.

Diseases. Root fungus is one of our more serious problems. For years we were plagued with phytophthora, and could not get rid of it in spite of major efforts with currently available fungicides. We reduced the problem when we changed our soil mix and substituted fibre pots (Western) for the thick walled black molded plastic containers we were using. The combination of poor aeration and overheating of soil in the container had been a major contributing factor to the fungus diseases.

We continue occasionally to have a serious phytophthora infection of either our plants' roots or stems and foliage. The infection develops rapidly over a great number of plants, and after several such experiences, we now review our nursery activities for the past year, and can determine a time at which we may have injured the roots of the plants. We believe this is the basic cause of nearly all of the root infection and stem infection problems we have.

Injury to roots is most generally caused by the application of too strong a fertilizer or too much fertilizer. Not always will the foliage or tips of the leaves burn. Sometimes the effect is more subtle. Foliage will slightly curl or leaves droop almost unnoticeably.

We have also damaged roots by the application of "safe" herbicides. While the rhododendrons in the containers survived the application, the opportunity for root infection was wide open, and more often than not during the first warm days of summer we would notice the first signs of phytophthora. At this time, we are most reluctant to apply any type of herbicide to a container-grown rhododendron.

Chemical damage to the root system of container-grown rhododendrons in a soilless medium is a very easy thing. Once accomplished, there is really no recovery of the plant. It should be discarded. Container plants are completely unforgiving. With field-grown stock it is another story. We maintain a stock block of over 1500 field-grown plants of various ages. At no time have we ever damaged field plants with identical applications which eliminated container plants.

We feel that with proper containers placed on a well drained gravel bed, a proper growing medium, and the avoidance of damaging roots with fertilizer or herbicides, one

can just about overcome fungus problems without the aid of expensive chemicals.

Propagation. We root our cuttings in a conventional greenhouse with bottom heat. Cuttings are placed in deep beds of a mix of perlite and peat moss. Overhead mist is provided. At Fort Bragg, the mist is not a critical factor.

The most critical factor for us is the condition of the wood selected for propagation. Initially, we were forced to take wood from our container-grown plants. This was always an uncertain effort because sometimes the plants we cut from were scheduled for sale, and we did not want to mar the appearance of the plant. Also, the container stock was sometimes overfed or underwatered, and always the condition of the wood was irregular.

In time, we developed a field-grown block of stock plants. Cutting wood from established field-grown plants is superior for our use to wood taken from our container-grown stock. Some cultivars we had considered discontinuing because of propagation difficulties, reversed themselves and became relatively easy to propagate after we commenced using wood from field-grown stock.

Management of the stock block is still new to us. We do not know to what extent we can cut our plants, but we are certain that a major management effort is required.

Fertilization. Our fertilization program combines liquid feeding both overhead and by hand, and dry application by hand.

At the time of canning we apply Osmocote (9 month formula) as a top dressing, and water in. In the case of our gallon cans, we then allow plants to grow approximately 3 months after canning, and then begin an overhead liquid feeding program based on the plants' needs as determined by soil tests. Feeding is every week.

Our containers, two gallons and larger, in the open, are fed dry by hand. This too commences approximately 90 days after initial canning and, generally, application is made about every six weeks. This program has been subject to many changes but the philosophy of a dry application by hand on our larger plants is our guide.

We have, on occasion, overfed our plants to the extent that the initial flush of new growth in the spring was very lush. There was no fertilizer damage to roots or foliage but we feel that the combination of very heavy, soft growth, and overhead watering was responsible for inducing stem and foliage infections which ultimately led to the death of entire limbs and

sometimes entire plants. We have also slightly damaged the surface roots with fertilizer and, subsequently, the damaged plants were attacked by root fungi. The same has happened when we have applied herbicides. This appears to point out that it is essential to protect the surface roots of rhododendrons. We have discovered no safe herbicide, and all fertilizers will burn if not used with utmost caution.

Grooming. Shaping of container plants is a chore we have to perform with diligence each spring. Actually, we continue to shape up through early July. After this time, we allow any started growth to continue undisturbed because there is not sufficient growing time left for new growth to develop completely.

The first shaping is done when we place 4" pots into gallon containers. We pinch out all growth buds on all plant tips. After the plants are canned and growing we continue to inspect them and pinch back all plants that have not developed at least four shoots.

One gallon plants shifted into two gallons are disbudded at the time of canning and again we continue to groom the plants after canning, shaping them to be tight and heavy. All of our canning is done when the plants are dormant. We generally do not continue to grow plants that do not respond to shaping or do not flower bud after pinching.

As mentioned earlier, some cultivars are best suited for five-gallon sizes. These we produce by shifting a one-gallon plant up to a 5-gallon size and allowing it to grow on for nearly two additional years. We give these the same attention as the gallons and twos the first year, but the second year we may allow them to make a natural growth without too much additional pinching, though we may have to prune suckers or wild shoots.

On some cultivars, as Anton Van Welie, Pink Pearl and others, we completely remove all of the soft first flush of growth and then allow a second flush to develop naturally. This will be a much more compact flush with lighter weight wood but substantial enough to provide a good base for the following year's growth. We learned to do this after years of having the strong north winds of spring knock the elongated shoots from the plants and then having the plants develop into more attractive specimens later in the summer. Sometimes frosts damage the early flush of growth; we then remove all shoots, damaged or not, from the affected plants.

Irrigation. While we water most of our plants overhead by means of impact sprinklers, we believe that an emitter system of irrigation is a better procedure. We have experimented sufficiently to recognize that this is possible, and have discovered

excellent types of valves and emitters that will develop a very efficient system.

Our conversion has been slow because of decisions we had to make regarding spacing, sizes of containers, and the type of bed we were to grow the plants on. But within this next year, we plan to install a complete system for a block of two-gallon containers using the Stuppy Turret Head emitters, electric valves with built-in batteries, and a water recovery system for irrigation of our block of stock plants.

Sales. Acceptance of container-grown rhododendrons has always been excellent. Buyers want to buy container-grown stock in ever increasing quantities. Growers, eager to make plants available, should be very careful not to obligate themselves beyond what is possible. Not all rhododendrons perform well in containers. Plants grown in areas other than Fort Bragg will not respond as ours do here. But one truth is probably universal for all container rhododendrons everywhere and that is, a good root system must be established and not allowed to be damaged, before any type of a plant can be grown or success assured.

BOB TICKNOR: Now, let's have some questions for our panelists.

VOICE: Barrie Coate, when you collect eucalyptus seeds, what tips can you give us in getting the seed out of the pods?

BARRIE COATE: We collect the seed virtually anytime but we sow them in the spring. We extract the seed from the seed pods immediately after we collect and dry the seed pods. All we do is put them in envelopes in a warm place — not in the direct sun, but in a warm place, and the seed pods gradually open. In a week or thereabouts vigorously shake the container, the envelope, and you are left with an envelope full of seeds. We found that it does not pay to keep the seed pods and go over them again and again and try to get every last bit of seed. We found that the first seeds to come out are the best; when you get them out, throw the seed pods away.

BILL BARR: I might say to Hildegarde that it probably was slime mold on the seed flat or spore flats of her ferns. Increasing light probably would reduce it. I would like to ask here what rate of Konsan and Ban-Rot she uses to control fungus in fern spore flats?

HILDEGARDE SANDERS: One-fourth teaspoon of Ban-Rot and ½ teaspoon of Konsan per gallon.

VOICE: Is there any information about the possibility of an isolated juvenile hormone that could control juvenility?

DALE KESTER: Basically the answer is no, but we can

make a comment. Certain chemicals — hormones — have been associated with juvenility and certainly the main one is gibberellic acid. Ivy reversion from the adult to the juvenile form can be produced experimentally by gibberellic acid. There was a paper at the juvenility conference in Beltsville of an extract of tobacco — DNA from the flowering phase — which they injected into juvenile plants and produced flowering. But they also had to be sure that the leaves were removed from the juvenile part. This is an example of the kind of thing that we may be talking about in the future. We may have to go back to basic parts of the cell, the DNA and RNA. The implication is that you could program plants to behave in a directed manner. Whether or not this is going to happen in the future is really hard to say.

BRUCE BRIGGS: Can you accept the statement that the root system is always juvenile?

DALE KESTER: It's a question of definition, perhaps. It is certainly true that one of the ways to produce a reversion is to propagate by root cuttings. The adventitious shoots that come out of the roots are juvenile in appearance and I think we can say they are juvenile. There was a very interesting report by Professor Schwabe in Wye College in England. He took an adult apple cultivar which was very difficult to root and managed to get some roots on stems; from those roots he did stimulate adventitious shoots, which were juvenile. The interesting thing was that the shoots were juvenile as for rooting and could be rooted as cuttings. You would assume then that if they were juvenile they would be slow to flower. But he found that they were flowering in two years, which is rapid. Perhaps they were juvenile for rooting but not juvenile for other factors, as flowering.

BILL LIBBY: Question for Barrie Coate. Do you use the same medium in the seed flats, peat pots and the gallon cans?

BARRIE COATE: No, we use a sterile inert mix of peat moss and Sponge Rok in both cutting flats and seed flats in the nursery. In the liner pot mix, we use a mix that we are buying already made which has fertilizers in it and contains volcanic rock, Sponge Rok, fir bark, peat moss, and sand. In the gallon and 5-gallon soil mix we have a much less sophisticated medium: mushroom compost, sawdust, and sand. It has the same basic fertilizer combination that Soil & Plant Lab recommends for most things. In addition, we use a small amount of Osmocote, 18-6-12, directly under the plant when we plant it. We use half a teaspoon in a gallon and about a teaspoon in fives. That is, directly under the root system. In addition to that we have liquid fertilizer in the irrigation injector.

BILL LIBBY: Do you find mycorrhiza on the eucalyptus?

BARRIE COATE: I wish I knew the answer. It is a field that has been neglected. I think it is important, perhaps more for some species than others. I do believe eucalyptus is one of the genera that would respond better if we had the right mycorrhiza provided for them. I don't have the feeling that we are doing that. We hope the mushroom compost is providing a few of the things of that nature but, frankly, I can't give you any scientific answers.

BILL LIBBY: How are you doing on rooting eucalyptus?

BARRIE COATE: Zero. I have tried it, I have tried grafting, various kinds, and frankly we are not large enough to provide research of that depth. I wish we could. There is a wide open market for cutting-grown *Eucalyptus ficifolia*, for example, The closest we can come is being very careful about our seed source.

ROOT PROMOTION ON STEM CUTTINGS OF SEVERAL ORNAMENTAL PLANT SPECIES BY ACID OR BASE PRETREATMENT

C.I. LEE, J.L. PAUL and W.P. HACKETT

Department of Environmental Horticulture
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Abstract. Rooting of stem cuttings of *Bouganvillea*, *Ceratonia siliqua*, *Chrysanthemum morifolium*, *Euonymus japonica*, *Euphorbia pulcherrima*, *Hedera helix*, *Trachelospermum jasminoides*, sp., *Juglans hindsii*, *Pistacia chinensis* and *Salix. laevigata* is greatly promoted by dipping in H_2SO_4 prior to applying indolebutyric acid. On the other hand, NaOH treatment results in considerable increase of rooting of cuttings of azalea, *Bougainvillea* sp., *Liquidambar styraciflua*, Osmanthus heterophyllus and Pinus radiata.

Auxin has varying degrees of effectiveness in promoting adventitious root formation in stem cuttings of many plant species. It has been suggested that auxin in the promotion of growth of *Avena* coleoptile is via induction of hydrogen ion secretion and cell wall acidification (2, 4). Acidification of the cell wall enhances its extensibility either by cell wall-loosening enzymes (3) or by breaking acid-labile links non-enzymatically (4). Media of low pH also show effects similar to that of auxin on the growth of *Avena* coleoptile (1). If at least part of the effect of auxin is cell wall loosening due to enhanced acidity, then pretreatment of cuttings in acid may further stimulate root-

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Abstract. Rooting of stem cuttings of *Bouganvillea*, *Ceratonia siliqua*, *Chrysanthemum morifolium*, *Euonymus japonica*, *Euphorbia pulcherrima*, *Hedera helix*, *Trachelospermum jasminoides*, sp., *Juglans hindsii*, *Pistacia chinensis* and *Salix. laevigata* is greatly promoted by dipping in H_2SO_4 prior to applying indolebutyric acid. On the other hand, NaOH treatment results in considerable increase of rooting of cuttings of azalea, *Bougainvillea* sp., *Liquidambar styraciflua*, Osmanthus heterophyllus and Pinus radiata.

Auxin has varying degrees of effectiveness in promoting adventitious root formation in stem cuttings of many plant species. It has been suggested that auxin in the promotion of growth of *Avena* coleoptile is via induction of hydrogen ion secretion and cell wall acidification (2, 4). Acidification of the cell wall enhances its extensibility either by cell wall-loosening enzymes (3) or by breaking acid-labile links non-enzymatically (4). Media of low pH also show effects similar to that of auxin on the growth of *Avena* coleoptile (1). If at least part of the effect of auxin is cell wall loosening due to enhanced acidity, then pretreatment of cuttings in acid may further stimulate root-

ing ability. The purpose of this study was to determine the influence of acid or base pretreatment of stem cuttings upon the rooting ability of several ornamental plants.

Sulfuric acid and sodium hydroxide were used as acid and base respectively. For determination of optimum concn of H_2SO_4, a preliminary experiment was conducted with the cuttings of *Phaseolus aureus*, *Chrysanthemum* 'Golden Anne' and *Salix laevigata*. Treatment with 2N H_2SO_4 for 15 sec dipping without IBA treatment was found to be most promotive in the rooting of all three plants and Fig. 1 shows the rooting response of chrysanthemum cuttings as a function of dipping time in 2N H_2SO_4. Similarly, NaOH solution of pH 10.5 for 10 min soaking gave the best result in the rooting of *Bougainvillea* 'San Diego Red'. Therefore, the concn of acid or base mentioned above was used in this study, although optimum dosage was not determined in other plant species.

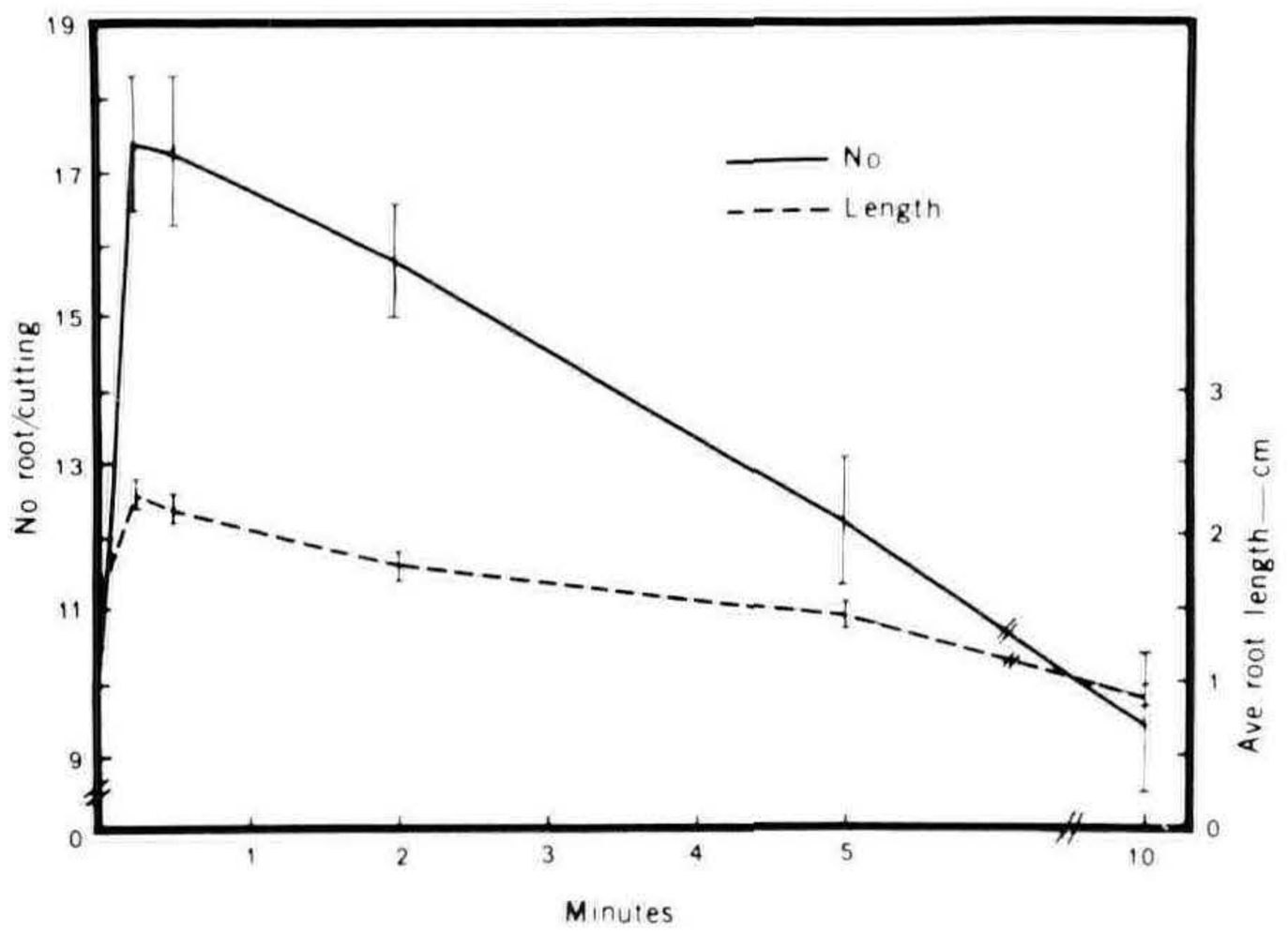

Figure 1. Rooting of *Chrysanthemum* 'Golden Anne' cuttings dipped in 2N H_2SO_4 as a function of time.

Thirty cuttings of each plant species listed in Table 1 and 2 were treated with the acid or base, washed with distilled water and then dipped in a 3000 ppm aqueous solution of the K-salt of indolebutyric acid (K-IBA) for 10 sec for herbaceous cuttings and 20 sec for hardwood cuttings. Thirty cuttings treated with K-IBA alone served as controls. Cuttings of azalea, *Bougainvillea*, *Euphorbia*, *Liquidambar*, *Osmanthus* and *Pinus* were placed in acid rooting medium (unlimed sphagnum peat + perlite 1:1 v/v) and cuttings of other species were placed in neutral medium (perlite + vermiculite 1:1 v/v). Previous work indicated that these species root best in these rooting media. All cuttings were rooted under intermittent mist with a 16 hr photoperiod.

Table 1. Promotion of rooting in certain ornamental plants by acid pretreatment.

Species	No. days to harvest	Treatment: IBA Percent rooting	IBA No.[z]	IBA Length[y]	H_2SO_4 + IBA Percent rooting	H_2SO_4 + IBA No.	H_2SO_4 + IBA Length
Bougainvillea 'San Diego Red'	28	100	19.1 ± 2.8[x]	-	100	27.1 ± 4.4	-
Ceratonia siliqua (Jan.)[w]	28	93	13.9 ± 2.5	2.5 ± 0.2	100	18.1 ± 3.1	3.5 ± 0.2
Ceratonia siliqua (June)[w]	28	20	2.0 ± 1.0	3.9 ± 1.7	75	4.7 ± 0.9	3.8 ± 0.7
Chrysanthemum 'Golden Anne'	12	100	87.2 ± 4.2	1.6 ± 0.1	100	105.5 ± 3.2	1.8 ± 0.1
Chrysanthemum 'Mandalay'	12	100	62.9 ± 3.5	-	100	77.3 ± 3.4	-
Euonymus japonica 'Yellow Edge'	47	85	11.7 ± 2.6	1.6 ± 0.2	100	27.2 ± 2.7	2.3 ± 0.2
Euphorbia pulcherrima 'Eckspoint C-1 Red'	21	100	29.5 ± 2.6	1.3 ± 0.1	100	39.0 ± 1.3	2.1 ± 0.2
Hedera helix (adult)	25	100	16.3 ± 2.1	0.9 ± 0.1	100	26.8 ± 2.3	1.1 ± 0.1
Trachelospermum jasminoides	42	53	23.5 ± 7.2	-	87	29.0 ± 6.6	-
Juglans hindsii	38	80	4.4 ± 0.8	4.7 ± 0.8	100	7.9 ± 1.2	7.3 ± 1.0
Pistacia chinensis	42	28	3.7 ± 0.6	-	70	3.2 ± 0.4	-
Salix laevigata	12	95	20.9 ± 2.4	3.4 ± 0.4	100	26.7 ± 2.9	3.9 ± 0.3

[z] No. of roots/rooted cutting.

[y] Ave. root length (cm).

[x] Mean and standard error of the mean.

[w] Jan. and June indicates month when cuttings were taken.

Table 2. Promotion of rooting in certain ornamental plants by base pretreatment.

Species	No. days to harvest	Treatment: IBA Percent rooting	IBA No.[z]	NaOH ± IBA Percent rooting	NaOH ± IBA No.
Azalea 'Sweetheart Supreme'	42	90	9.6 ± 1.7[y]	90	20.8 ± 3.2
Bougainvillea 'San Diego Red'	28	100	19.1 ± 2.8	100	33.1 ± 3.5
Liquidambar styraciflua	42	100	34.7 ± 1.5	100	42.6 ± 2.0
Osmanthus heterophyllus	33	75	5.4 ± 1.0	100	8.6 ± 0.6
Pinus radiata	90	60	4.0 ± 0.5	93	3.9 ± 0.3

[z] No. of roots/rooted cutting

[y] Mean and standard error of the mean.

Acid or base pretreatment significantly influenced the rooting ability of cuttings studied (Table 1 and 2). Stem cuttings of *Bougainvillea*, *Ceratonia*, *Chrysanthemum*, *Euonymus*, *Euphorbia*, *Hedera* (adult form), *Juglans* (cuttings from adventitious shoots of 5-yr-old tree) and *Salix* (softwood) had a significantly greater number of roots as a result of acid pretreatment. On the other hand, base pretreatment significantly increased the number of roots in cuttings of azalea (taken in Jan.), *Liquidambar* (semi-hardwood) and *Osmanthus* (semi-hardwood). Rooting of *Bougainvillea* was enhanced by both acid and base pretreatment. Rooting percentages of relatively difficult-to-root cuttings such as *Ceratonia* (taken in June), *Trachelospermum* (hardwood), *Osmanthus*, *Pistacia* (semi-hardwood cuttings from 2-yr-old seedlings), and *Pinus* (taken in Jan.) were increased by the pretreatment. Also, cuttings treated wth H_2SO_4 produced longer roots in *Ceratonia* (taken in Jan.), *Euonymus*, *Euphorbia*, and *Juglans*. The pretreatment, however, depressed rooting of *Cotoneaster* sp. and *Xylosma congestum* (data not shown). Concentrations of acid or base and time of pretreatment may result in toxic effects for these plants. Generally, acid pretreatment promoted rooting of plants native to near neutral or alkaline soil and base pretreated cuttings increased rooting ability of those native to acid soil.

Cuttings of azalea treated with base remained turgid and leaves did not show any visual water stress during the rooting period, whereas the control showed some wilting under the environmental conditions described (Fig. 2). Similar results were also observed in the cuttings of *Chrysanthemum* dipped in acid. The pretreatment also reduced loss of foliage of woody species in which root initiation takes more than 6 weeks.

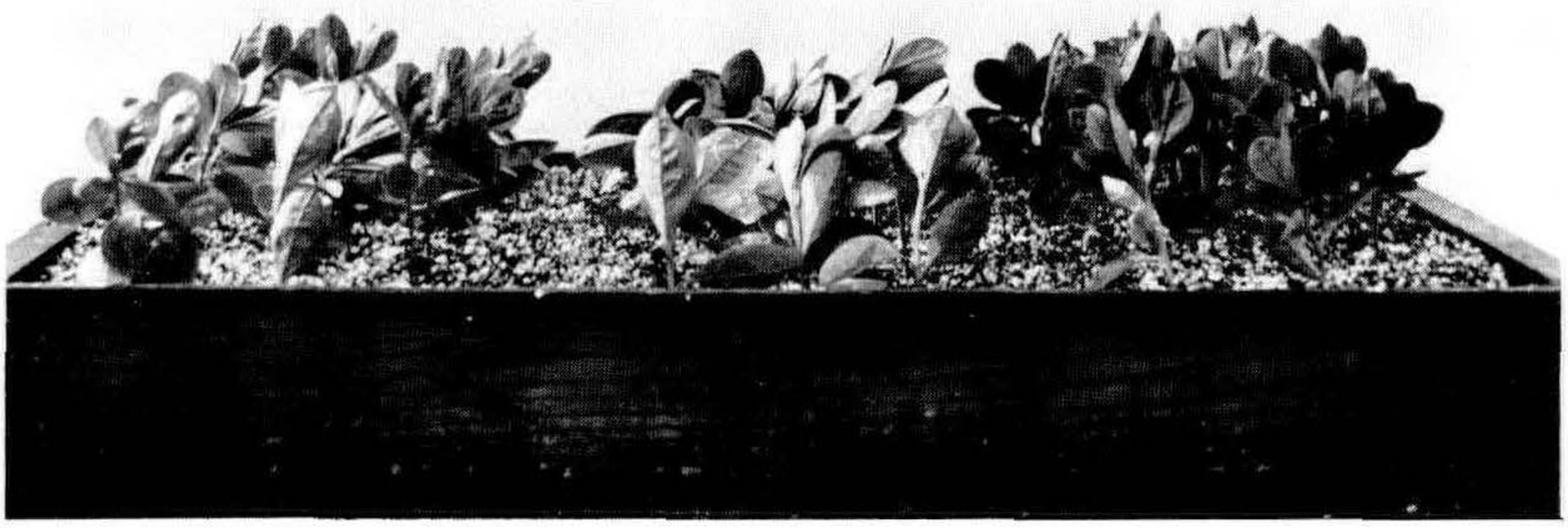

Figure 2. Azalea 'Sweetheart Supreme' cuttings treated with NaOH (*right*) showing turgid leaves and stems after planting. Control (*left*) and acid-treated cuttings (*center*) showed some water stress.

In *Chrysanthemum* sulfuric acid treatment alone hastened root initiation and promoted rooting quality as well (Table 3). Protuberances on the stem were observed on the 4th day in acid treated cuttings but not in control cuttings. Acid treated cuttings rooted 100% on the 8th day but control cuttings rooted only 75%. At the time of harvest (12th day) total root length per cutting was 37.0 cm compared to 16.5 cm for the control.

These results lead us to suggest that a short exposure to acid may break acid-labile linkages (Ca bridge) in the cell walls of calciphilous plants. The base pretreatment may break base-labile linkages (ester bridge) in the cell walls of acid-loving or acid-tolerating plants. Such reactions may loosen cell walls, increase water permeability (5), facilitate absorption of applied auxin and/or emergence of root initials. The relation of acid or base promotion of root initiation to auxin-induced root initiation has not been studied in detail. It is clear (Fig. 1 and Table 3) that H_2SO_4 alone can promote root initiation. This could be a direct morphogenetic effect of acid or an interaction of the acid with endogenous morphogenetic factors such as auxin. At present the mode of action of acid or base treatment is being investigated.

Table 3. Rooting of *Chrysanthemum* 'Golden Anne' cuttings treated with or without 2N H_2SO_4 alone for 15 sec after 8 and 12 days.

No days after *planting*	*Treatment*	Percent *rooting*	No. roots/ *cutting*	Aver. root *length (mm)*	Total root length/ *cutting (mm)*
8	H_20	75	3.6 ± 0.6[z]	2.7 ± 0.4	15.5 ± 3.4
	H_2SO_4	100	5.9 ± 0.6	5.2 ± 0.5	37.5 ± 6.5
12	H_20	100	9.1 ± 0.7	16.1 ± 1.3	165.3 ± 22.5
	H_2SO_4	100	14.9 ± 0.8	23.3 ± 1.2	370.0 ± 34.7

[z] Mean and standard error of the mean.

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THE CREATIVE SEARCH FOR NEW F_1 HYBRID FLOWERS

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There is a small group of companies, about 6 in the U.S. and perhaps 15 worldwide, that have caused a gardening revolution during the last 20 years. This revolution is the change by the gardening public from the sowing of seed in the garden to the purchasing and planting of started plants. The companies largely responsible for this revolution are those developing F_1 hybrid annual flowers.

It is not a coincidence that the rapid development of the bedding plant industry coincides with the tremendous increase in the use of the F_1 method for the production of flower seed. In fact, neither industry could have developed to the extent they have without the other. The bedding plant industry needed and has used the greatly improved cultivars in order to have a superior product which the public would buy, and the seed companies needed the professional grower who had the experience and facilities to grow the expensive seeds.

Hybrid flowers offer the same advantages over open-pollinated sorts that are found in vegetables and field crops: those of uniformity and increased vigor resulting in stronger plant growth; more abundant flowering and larger flowers blooming over a longer season; a generally all-around superior garden plant. Also in flowers the hybrid method can result in flower colors, flower types, and habits that are the result of the heterozygous condition for certain genes.

There is a truly amazing contrast between the small-flowered, poor colored, and usually rather weak-growing and loose petunias that were sold before the F_1 hybrids, and the large-flowered, vigorous, compact, very free-flowering, pastel and bright colored hybrid petunias. The contrast between an open pollinated snapdragon mixture and vigorous hybrids like the Rockets, and the difference between the new F_1 semi-dwarf African marigolds and the existing open pollinated cultivars is equally great.

Today one can purchase F_1 hybrids of at least 15 species of annual garden flowers, including ageratum, begonia (fibrous rooted), dianthus, geranium, iceland poppy, impatiens, marigold (*Tagetes erecta* and *Tagetes erecta* × *T. patula*), nicotiana, pansy, petunia, primula, portulaca, salpiglossis, snapdragon, and zinnia. In addition, F_1 hybrid seed of four greenhouse pot plants is available: calceolaria, cyclamen,

gloxinia, and saintpaulia. Twenty years ago F_1 hybrids were only available in three species: petunia, begonia, and the greenhouse cut flower snapdragon.

It is interesting to note that not only has the flower seed industry intensively used this method of breeding, but was one of the first to offer commercial seed of F_1 hybrids with the introduction of *Begonia gracilis* 'Prima Donna' by Ernst Benary in 1909.

Economic as well as horticultural reasons have influenced the rapid and widespread use of F_1 hybrid flowers.

Because of the relatively small amount of seed needed when compared to a vegetable or field crop, hybrids can be hand produced in flower species that would be prohibitively expensive in some other crops. A large proportion of the hybrid seed is sold to professional growers who in turn market plants to the consumer.

The desire to protect one's product has also been a strong contributing factor to the rapid increase in the adoption of the F_1 hybrid method. Having this protection has permitted companies to invest more in their breeding programs, both in facilities and in personnel.

ADVANTAGES OF F_1 HYBRIDS

Let me enlarge on the advantages of F_1 hybrids and the accomplishment a breeder can make using this breeding method in addition to the most obvious one of hybrid vigor or heterosis.

Two important flower types in petunia, the large-flowered or grandiflora type and the double-flowered form are completely dependent upon the hybrid method for production. The grandiflora character is semi-lethal in the homozygous state giving a very weak plant. The character is dominant to the small-flowered or multiflora type. Commercial F_1 hybrid grandiflora petunia seed is produced by crossing multiflora and grandiflora lines, usually using the multiflora line as the seed parent. Likewise double-flowered petunia seed production is dependent upon the hybrid method. Double-flowered petunia lines have pollen, but are essentially female sterile with only an occasional functional pistil. In commercial seed production the double-flowered inbred lines are maintained vegetatively and used as pollen parents in crosses with single-flowered lines. The double-flowered character is dominant and so the resultant F_1 hybrid is double-flowered. Most double parents are small-flowered, so depending upon the flower type of the single parent, the F_1 hybrid is either multiflora double or grandiflora double.

In both zinnia and African marigolds some recent desirable intermediate habit types result from crossing tall and very dwarf forms. The F_1's are intermediate and cannot be "trued up". 'Peter Pan' zinnias and marigold cultivars, Apollo, Moonshot and the Lady hybrids, are examples of this.

In some genera, such as *Dianthus*, there is, during the inbreeding process to get uniformity, a strong inbreeding depression or loss of vigor. Species such as this are good candidates for using the hybrid method.

Also by the hybrid method very desirable F_1 hybrids can sometimes be made between different species. *Dianthus* 'Queen of Hearts' is an F_1 hybrid between an inbred line of *Dianthus chinensis* and *D. barbatus*. The F_1 hybrid is sterile, as one would expect, and is very free blooming. The very popular triploid marigolds, hybrids between *Tagetes erecta* and *T. patula*, are another example of F_1 hybrids between species. Like the 'Queen of Hearts' dianthus, these hybrids are very free blooming and superior in many horticultural traits to either species.

In recent years there has been a dramatic shift in the method of propagation of garden geraniums from asexual propagation by cuttings to the growing of plants from seeds. This change has been possible because of the outstanding new F_1 hybrid cultivars that have been developed. These are early and free blooming, with compact habit giving much better garden performance than the cutting grown cultivars.

DEVELOPMENT OF NEW F_1 HYBRID CULTIVARS

There are three steps in the development of a new F_1 hybrid cultivar.

(1) *The development of inbred lines.* Inbred lines may be selected out of commercial open-pollinated cultivars, but more likely will be developed from recombination of segregating breeding material. For example, in the development of inbred lines to produce snapdragon 'Bright Butterflies' by our company, over 15,000 F_2 plants were grown from crosses of strong normal-flowered snapdragons and 'Juliwa' snapdragons with the desired open-faced flower form. From these populations 26 plants with the character we wanted were selected. These were inbred and further selected to give us the inbred lines used to make the F_1 hybrid mixture 'Bright Butterflies'.

(2) *Making test hybrids.* The breeder armed with knowledge of the inheritance of the characters, such as flower color, flower form and habit, plans and makes hybrids which he predicts will give the F_1 hybrid he wants.

(3) *Testing of hybrids.* These are tested in the greenhouse

for performance at the time a plant grower would sell them and in the field for garden performance. Before a cultivar is introduced it is tested in trial gardens conducted by seed companies, public parks and universities. The University of Illinois and Pennsylvania State University have been leaders in this type of testing.

Particularly outstanding new developments may be entered in competitive trials such as the All-American Selections or the more recently formed counterparts in Europe, the All-Britain Trials and Fleuroselect. Winners of awards in these trials receive promotion that results in greatly increased sales.

SEED PRODUCTION

Many of the F_1 hybrid cultivars in crops such as petunia, snapdragon and pansy are produced by hand emasculation and pollination. Because of the large amount of hand labor involved, the production is centered in low labor cost areas of the world such as Central America and parts of Asia. These areas also have the advantage of climates that permit construction of relatively inexpensive greenhouses without heating or cooling facilities.

In some crops male-steriles have been used to eliminate emasculation, but the plants are still pollinated and the seed picked by hand. Examples of this are geraniums and dianthus. F_1 hybrid marigolds are produced in field plots using alternating rows of seed and pollen lines. Two distinct forms of pollen sterility are used in the seed line. One method is to rogue a population segregating for full double (all ray flowers) and semi-double, leaving only the full double type. The other method is to incorporate a recessive apetalous character into the seed line. The line maintained in a 50:50 normal to apetalous ratio is rogued to the apetalous type. Neither type of male sterility is without its problems. The full double method is difficult because age and environmental stress can cause plants that had been full double to produce some flowers with disc flowers. Pollination is a problem with the apetalous flower form. Not having petals, it is less attractive to pollinating insects.

Hybrid zinnia seed is produced using an apetalous character similar to the one in marigolds and maintained in the same manner. However, the apetalous flower form is even less attractive to insects than in the marigold, and the pollen is usually collected and applied by hand.

If you are using F_1 hybrid flowers in your business, planting them in your garden, or only enjoying them in parks and gardens, I hope you have a better understanding of what is involved in their breeding and production.

RAY HASEK: Now is the time for questions for our panelists.

VOICE: In using the acids or bases, would there be a problem with the workers using them because of their caustic nature — being injured by them?

WES HACKETT: I certainly think that is a concern. I talked with a man from Monrovia Nursery who said they were trying it experimentally and I am not sure whether they had involved their workers or not, or whether they were using other kinds of personnel to do that work.

BILL BARR: Yes, we are using it for experimental purposes and are just letting one person do all the work with the acid and bases and that one person does all the preparation.

WES HACKETT: You do have to realize that sodium hydroxide is lye; it is a very caustic material. Sulfuric acid is also a very caustic material. It could be very injurious to eyes and other delicate parts of the human anatomy.

JOLLY BATCHELLER: Do you use total immersion of the cuttings?

WES HACKETT: No, just the base of the cuttings. The same way you would dip a cutting into an IBA solution.

VOICE: What is the normality of the sodium hydroxide solution?

WES HACKETT: pH is 10.5. This is the easiest way to measure it.

VOICE: What would be the concentration percentage you are using of sulfuric acid, sodium hydroxide, and IBA?

WES HACKETT: We pre-treat with either the acid or base depending on the species. The acid is the 2 N solution; take concentrated sulfuric acid, dilute it down to 2 N. With sodium hydroxide the easiest way to prepare the solution is with a pH meter. We add the concentrate NaOH to water until the pH gets to 10.5. The cuttings are then dipped for an appropriate length of time, washed thoroughly, and then re-dipped in whatever kind of auxin material you use. We use 3000 ppm as a general concentration of IBA.

BRUCE BRIGGS: Do you have any comparisons where you wound the cuttings.

WES HACKETT: No, we did not compare wounding with the acid-base treatment.

PHILIP BARKER: I would like to ask Harold Tukey a question. Would you explain what you know about the triggering mechanism of fall leaf coloration.

HAROLD TUKEY: This information is in the horticultural

and plant physiology literature. The rest, dormancy, begins in many woody plants in mid-summer with the setting of a terminal bud, which involves a hormone relationship triggered in many plants by a photoperiod reaction. As the fall season approaches, the red-colored pigments, anthocyanins, begin to accumulate. This is enhanced by low temperatures, by a good carbohydrate supply, and perhaps by nutrients such as nitrogen and potassium. But the process begins in mid-summer.

VOICE: Mr. Goldsmith, could you discuss your record keeping system in your breeding work?

GLENN GOLDSMITH: Actually you might be surprised by the lack of detailed note taking. What we want to know in most cases is "what is the best selection or hybrid of a group of a similar type?" My book therefore is filled with ×'s, double ×'s and triple ×'s to indicate the best within a series. I will make detailed notes on new breeding material and hybrid combinations. We also don't save any selections that we don't intend to plant the next generation. We automatically sow everything saved the year before. As some of these cultivars approach the finished product, we will get involved more with our sales people, and they will take more detailed notes so that they can do the descriptive and catalogue work. We use a pedigree system in our inbreeding, in which each year we simply add another dash and 1, 2, 3, depending on the selection. This system is pretty much patterned after what I used at Pan American Seeds when I was there.

PLANT HUNTING IN ENGLISH GARDENS

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Large nurseries producing batches of plants by the thousands and plush garden centres, where one has to thread a delicate path through concrete and plastic paraphernalia before finding the plants, are as remote from my kind of nursery as is a Texas ranch from a Herefordshire smallholding. I don't feel in the least envious (I suppose some might call it ambitious); in fact, I consider myself lucky to be running the sort of tiny concern which relies upon the production of interesting plants for it's survival. Perhaps, we can, quite easily, grow 100 plants of *Anchusa caespitosa* and several hundred *Romneya coulteri*. But it is equally as satisfying to get out annual crop of 10 plants of *Sanguinaria canadensis* 'Plena'.

So many of our plants provide just the odd few cuttings or the occasional crop of seed. It is worthwhile asking the question "Would there by any point in producing such plants in quantity, even if it were possible?" True enough, a certain element of the gardening public will always show tremendous interest in the more unusual type of plant. But if plants like the *Anchusa* and *Sanguinaria* were as widely grown and readily available as say *Mahonia japonica*, how long would their special appeal last? There is nothing like familiarity for building up a healthy contempt for sales figures, especially if one's customers are mostly knowledgeable gardeners, who no longer possess the happy knack of killing plants off fairly rapidly!

It, therefore, follows that a matter of prime importance is the regular introduction of plants which are new to the nursery. How fortunate we are to be living in a country which is a veritable treasure house as far as plants are concerned. Whether it is the broad acres around a stately home, the plant-packed confines of a botanic garden or the seemingly most humble of cottage gardens, the range and long establishment of English gardens offer the plant collector an especially rich and varied hunting ground. How valuable this is to those of us who possess neither the time, knowledge, or resources to travel abroad in search of new plants. All around us are old favourites like the double-flowered sweet rocket, *Hesperis matronalis* 'Alba Plena', long since lost to nurseries, but, given to us some years ago by Mr. Eliot Hodgkin. Then, one can be given the occasional worthwhile newcomer, like *Dionysia aretioides*. Consider the thousands of really good plants which have been intro-

duced to this country, only to sink into near oblivion because no one has propagated and distributed them. The great collectors like Forrest and Wilson sent home so many plants which we hardly ever see today. Yet, a large number of them must still be growing in some gardens. Take, for example, *Corydalis cashmeriana*, which can be seen flourishing in gardens but can hardly be said to be widely grown.

Most gardeners are remarkably generous in giving material from their plants because they fully recognise the sound sense in having a reasonably wide distribution if the plant is to survive. It generally pays to be scrupulous as to one's methods of gathering materials. We remember the gentlemen who called on a great lady gardener to be told that she was engaged for some minutes — "would he care to walk around the garden?" Of course, the temptations presented by each border were far too great for him. Being the pre-polythene era, he tucked the cuttings under his hat, becoming so engrossed in his task that he lost count of time. Consequently, he suddenly bumped into his hostess around the corner and despite his state of confusion remembered his manners and raised his hat in greeting!

Not every plant will prove as valuable as the proud donor would have one believe. I still recall the person who was kind enough to present us with variegated ground elder (*Aegopodium podagraria* 'Variegatum'). Perhaps, garden centres could promote this plant as the ground cover discovery of the century!

Correct naming can be a considerable headache. It is often surprising to find how many people have no idea what they are growing. Perhaps it is less surprising to discover at some later date that you have been given the wrong name. *Aeonium tabulaeforme* is a most decorative plant in foliage and quite spectacular in flower. This had to lanquish for many years as "some sort of succulent, nearly hardy", before someone came along with the name. Many years ago we were given a young plant from a parent found growing on a rubbish heap in William Robinson's garden at Gravetye. The owner was happily calling it a "Dwarf Laburnum". Subsequent enquiries at Kew revealed it to be *Cytisus sessilifolius*, a plant long cultivated but hardly seen today. Naming is somewhat easier on the odd occasion when one is given a completely new cultivar. We were fortunate to be given cuttings of a dwarf form of *Hebe cupressoides*, now called *H.c.* 'Boughton Dome', which grows to around 40 cms. It makes a lovely shrub for the rock garden or heather bed as do so many in this useful genus.

Having got the initial stock growing we find it best to establish some plants to grow on to maturity, rather than rely en-

tirely upon propagation from the nursery stocks. The wide range of plants handled makes the latter difficult if something is missed at the appropriate time. Alpines and dwarf shrubs are grown in raised beds making cultivation relatively easy and, at the same time, providing excellent display areas. Given a safe number of stock plants (dependent upon the speed of growth and ease of propagation) nursery plants can be sold as and when available instead of waiting to build up large stocks. Unless one has a "sure-fire popular plant", the latter course can be a mistake in a small nursery.

Let me now introduce you to some of the plants which we have collected over the years in English Gardens.

Acanthopanax sieboldianus (A. pentaphyllus) 'Variegatus' must be one of the finest small growing, deciduous variegated shrubs. It is perfectly hardy with us and very decorative in form as well as leaf colour. Cuttings root quite readily. Other members of the genus can be propagated from root cuttings but the likelihood of producing green foliage would be too great in this instance.

Arundo dona × 'Variegata' came to us from a botanic garden. It is a striking plant of considerable architectural value in the garden, appreciating a reasonable amount of moisture. Judging by its potential for vigorous growth, it is possibly fortunate that it is not completely hardy in the Midlands. Division is the easiest means of propagation although stems will root from the nodes, under mist.

Cestrum parqui was given to us by that great gardener and collector of good plants, Mrs. Margery Fish. The plant was found in Chile in 1787, yet how often is it seen today? It needs the shelter of a west wall but that is not an insurmountable problem. During late July and August the plant, around 1.5m high, is wreathed in cool yellow blossoms, sweetly scented in the evenings. Half ripe cuttings root easily if the propagator has been able to stand the strange smell of the foliage!

Euphorbia nicaeensis is a plant which grows easily from seed. A specimen growing in a stony, well-drained and sunny spot will usually throw plenty of seedlings around the area. This is a spurge of considerable merit, coming into flower in early summer; the thin stems hold masses of bright lime-green heads into the autumn. Standing about 45 cm high and forming a neat mound, the whole effect is one of grace and colour combined.

Iris unguicularis 'Alba' is a rarely seen form of this justly popular winter-flowering plant. It grows very well in a rather impoverished condition, under the shelter of a sunny wall. Division is the only means of propagation and, since the plant is

not as vigorous as the type, stocks are not likely to be plentiful.

Itea ilicifolia originally came from western China in 1895. Our plant attracts more attention than any other shrub in the nursery during August, when the long tassles of blossoms (reminiscent of *Garrya*) cover the side of a potting shed. It grows very freely on a northwest wall, which is well clothed by the shiny, evergreen foliage through the year. Fairly ripe wood, taken with a heel, will root easily in late summer.

Leptosperum scoparium 'Nichollsii Nanum' must be one of the most attractive dwarf shrubs for a sheltered site in the peat bed or rock garden or for alpine house culture. The form of the plant, bronzed foliage, and bright red flowers, go to make up a plant of high quality, which never fails to attract attention. It does best in an acid soil and, in the Midlands, really requires some shelter in winter. Mature plants grow to about 20 cm × 40 cm. We root cuttings of half-ripe shoots.

Mahonia aquifolium 'Moseri' is one of the most sought after shrubs on the nursery. The striking apricot-coloured leaves in early spring always catch people's eyes. In fact, we often wish that it was a little less conspicuous! Not that propagation presents any particular problems; layers or cuttings are equally easy. Availability of material is the problem. To gain the best effect from mature plants it is advisable to layer or prune them back to encourage bushy growth, as opposed to the natural rather leggy habit. Obviously a plant for flower arrangers!

Meconopsis cambrica 'Flore Pleno' unlike the type plant, is a welcome addition of any garden. The bright orange, or yellow flowers last long in bloom and the plants seed quietly around without becoming too numerous. Most seedlings come true but one can find the odd single blossom. So, a small element of risk is involved in selling plants prior to flowering.

Oenothera macroglottis (O. *australis*) is reminiscent of the better known *O. caespitosa*, with white blossoms that fade to pink "on the morning after the night before". However, the flowers are larger, as is the foliage, which has a greyish tinge. *O. macroglottis* is also more reliably perennial, although some protection might be required in winter. The plant will run for a considerable distance. We have one which has travelled a distance of 2 m in one season. Our plants have not set any seed. We, therefore, propagate by lifting and potting the shoots arising from the underground running stems. The plant grows to about 25 cm high.

Origanum rotundifolium is a comparative newcomer to the range of interesting marjorams, which includes *O.* × *hybridum*, *O. dictamnus* and *O. amanum*. Only about 15 cm in height, it quickly forms a clump up to 60 cm across. The large, apple-

green bracts are decorative over a long period through the summer. Young shoots root well in spring and large clumps can be divided.

Paeonia mlokosewitschi has been with us since 1907 and still continues to be a much sought after plant. This herbaceous paeony must surely be one of the aristocrats of the English Garden. The red buds and pink and grey candlesticks of shoots, prior to flowering, are sufficient to justify a place in any garden. Then come the gorgeous silky, yellow flowers and, in early autumn, bright yellow and orange shades in the dying leaves. Division of large clumps is possible, even desirable, once in a while but seed remains virtually the only means of propagation commercially — and we all know how long it takes to produce a flowering-sized plant!

Phlox pilosa 'Chatahoochee' (20 cm) is a fairly recent introduction which always excites much comment. It carries such a wealth of intense mauve/blue flowers that we have to cut off the stems as soon as possible so that some shoots will be produced. Watering in dry weather helps the growth of the latter which will root quite easily. The plant grows best in acid soil.

Salvia multicaulis represents the many sages which we seem to have collected. The enormous bright purple/red bracts on this low shrubby plant (about 60 cm in flower) are quite extraordinarily spectacular. Understandably it is a popular plant with flower-arranging ladies, who are always open to buy a fast maturing plant which does not suffer from being cut back frequently. Cuttings taken either before or after flowering are successful. The plant needs a sunny, well-drained site.

Trachelium asperuloides (Diosphaeraa) makes a charming mound in a limestone scree bed or a showy plant for a pan in the alpine house. The plant comes from Greece and is hardy, although it might require some protection from winter rain. It is very free-flowering, the pale blue blossoms appear in July and August, at a time when few alpines give colour. Plants can be divided or cuttings may be taken after flowering.

Trillium grandiflorum 'Flore Pleno' is a great treasure which we had been seeking for years. The double white, almost camellia-shaped, flower heads have a most exotic appearance. Our plants are growing successfully in a bark/loam mixture under conditions which must really be too dry. We have not disturbed the plants yet but, when the times comes, division will be the method of increase. The prospect of stocks being plentiful seems more than remote. The one nursery offering plants at the moment charge !6 and it is likely that a high price level will be maintained.

Tropaiolum polyphyllum comes from Chile and Argentina

and was discovered in 1827. Even without the bright yellow/orange flowers, the intensely glaucous foliage sprawling over the ground or tumbling down a rock face or dry wall is worth growing the plant for. It is virtually hardy but we find that the tubers need to be established at a considerable depth, or beneath a rock, for safety. We know of several gardens where it is so well entrenched that it has become a weed and has to be thrown out periodically. All very fortunate for the nurseryman! If stock is in short supply, tubers may be cut into lengths with buds, during dormancy, and potted individually so as to avoid any disturbance once growth has started.

Verbena × hybrida 'Sissinghurst'. Here, no guarantees are offered as to the authenticity of the name! What is without any dispute is the fact that this is *the* plant for those who seek a quick turnover. Its vivid pink blossoms, sprawling for l m or so across create such excitement that we have to propagate the plant several times through the season. Cuttings root rapidly and make saleable plants bearing flowers with almost indecent speed. And — the key to financial success? The plant is not winter hardy in the Midlands but is so attractive that gardeners are quite prepared to buy plants each year.

Viola 'Irish Molly' is an old friend now in very short supply. Possibly not as vigorous a plant as in former days; one needs a constant supply of young plants to replenish stock. The unique coffee (or is it brandy?) colour makes it certain that every plant available will be sold. We all know that the public's interest in certain groups of plants ebbs and flows. At the moment, interest in named violas appears to be on the increase.

Having seen a tiny selection of the plants collected from English Gardens, I hope that you will have been reminded of the wealth of interesting material which is around us. There are many worthwhile plants growing in a comparatively small number of gardens. There are plants which merit wider distribution and, in some cases, plants which urgently need to be propagated to safeguard their survival.

The problems involved in growing such a wide range of plants on one small nursery must be obvious. But it is a fascinating task, full of surprises, delights and disappointments, laces with a constant flow of new knowledge, which is possibly why many of us are involved in horticulture.

SOME APPROACHES TO PROPAGATION PROBLEMS IN THE EARLY MULTIPLICATION OF NEW CLONES OF WOODY FRUIT PLANTS

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Fruit research stations repeatedly have to rapidly increase small quantities of new plant material for wider testing under commercial growing conditions. Those cultivars which meet exacting current day standards must then be rapidly multiplied so that they can be supplied to commercial nurseries specialising in elite stock propagation in sufficient quantity to justify the expense of setting up new production beds, often in isolation from existing material.

Very limited quantities of material are initially available when originally virus-infected clones are made "virus-free" by heat therapy which provides, in the first instance, one meristem to start the new clone. In the case of a newly bred cultivar, the original plant is often supplemented by others during the early screening procedures for disease resistance and propagation ability, but initially few plants are available.

Scion cultivars. A simple approach can be used for a new cultivar destined to become a scion cultivar because fruit cultivars are traditionally budded onto rootstocks which contribute specific characteristics of size control and cropping ability to the composite tree. Because the propagule is a bud, the objective is to produce as many of these as possible; this is done by budding or grafting some of the original material onto suitable rootstocks, which are virus-free and of sufficient vigour to encourage the production of large numbers of shoots. Budwood trees produced in this way are often referred to as "mother trees", despite their asexual role in propagation.

Rootstocks. Much greater difficulty is encountered in the early bulking of new cultivars destined as rootstocks because of the need to induce adventitious rooting from the stems of cuttings or layers. Successful rooting of cuttings usually comes from a special study of particular plants, justified by their commercial importance, as in the case of fruit rootstocks (1). It follows, therefore, that until potential rootstocks have been screened for rooting ability and any propagation problems overcome, attempts to root the small quantities of initially available material might result in irreplaceable losses. This particularly applies to the bulking-up of material such as rootstock M.9, whose importance as a dwarfing rootstock for intensive orchards has outweighed the fact that it is difficult to propagate,

and which recently needed to be quickly multiplied following introduction of virus-free material. The problem should not be as great in the future because of the current emphasis on ease-of-propagation during breeding and subsequent screening. An extreme example is the new cherry rootstock, 'Colt', which like other clones from crosses between *Prunus avium* and *P. pseudocerasus* produces preformed roots on current growing stems and roots readily from softwood (4) and hardwood cuttings. Our approach with difficult subjects has been to exploit the fact, as already discussed, that buds are produced more readily than adventitious roots on stems. Nurse-rootstocks have been grafted or budded with buds from the rootstock being bulked-up, so that the first stages in the multiplication programme have maximised shoot multiplication and ignored the rooting stage. When adequate numbers of shoots had been obtained in this way, rooting was induced either by earthing-up soil to the bases of low-budded shoots, or by using the shoots as cuttings, without the risk that some failures would jeopardise the programme (Table 1).

Table 1. Comparative schemes for multiplying one twenty-bud plant by conventional stooling, or by multiplying buds initially using nurse-rootstocks. (Assume twenty buds available per shoot per season).

STOOLING METHOD	NURSE-ROOTSTOCK METHOD
Year 1	
Plant established in nursery	*Spring: 5 × multiple bud grafts* worked onto nurse-rootstocks Summer: 300 buds produced and budded onto nurse-rootstocks
Year 2	
Cut to near ground level and 3 rooted shoots produced	6,000 buds produced and budded onto nurse-rootstocks
Year 3	
3 new plants established, 5 shoots produced by original plant	120,000 buds produced and budded at ground level onto nurse-rootstocks
Year 4	
9 + 5 rooted shoots produced, together with 4 established plants — total 18	*Approximately 100,000 rooted shoots harvested*
N.B. This figure may be doubled by growing-on non-rooted and small shoots from each year's crop.	N.B. In practice a target of 5 to 10,000 is usually set because of limitations from the availability of nurse-roots, land and labour. Success during the fourth year will mostly depend on the rooting ability of the "scion". Constricting with wire at the base of the shoot has been used to enhance rooting.

The characteristics required in nurse-rootstocks are that they should be freely available, virus-free, have distinctive growth, such as leaves or stems of a different colour to the scion, and induce vigorous growth in the scion. In apple rootstock multiplication programmes, *Malus* seedlings are suitable and seeds from 25 distinctive species or selections are being tested for their suitability as nurse-rootstocks. In species such as *Prunus* where, unlike *Malus*, some viruses are seed-transmitted, care must be taken to obtain seed from healthy trees.

In-vitro micropropagation. Multiplying plants by inducing meristematic tissue to proliferate under controlled conditions in sterilised culture media has been successfully applied to orchids and appears to offer potential for other herbaceous plants. Until recently, the prospects for using this method with woody plants were poor. Recent developments in which phloridzin, a phenolic glycoside naturally occurring in apples, has been shown to promote vigorous multiplication of apple meristems has greatly improved the potential use of *in-vitro* methods for woody plants. The use of relatively large pieces of vegetative buds as starting tissue and omitting cytokinin from the rooting stage of the culture also appears to significantly contribute to success (3). The principles of micropropagation are similar in some respects to those of the nurse-rootstock system, whereby the early stages of propagation are given over to multiplying vegetative shoots, with conditions subsequently changed to induce rooting at a final stage when failure of some propagules to root is least important.

Collection from the wild. When woody plants are collected from their natural habitat even less is known of their propagation potential than when they are derived from a breeding programme. Grafting onto rootstocks likely to be compatible with the collected material is an important first stage in ensuring its survival. Once established, marcotting, layering and cutting tests can be carried out to determine the best regenerative approach. If long-term cold storage is developed for woody plants, the same system will need to be introduced at periodic regenerating stages of the stored material. (2).

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PROPAGATION TECHNIQUES OBSERVED ON A RECENT TOUR OF AMERICA

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There would appear to be as many ways of producing any particular plant in the U.S. as there are in G.B. However, due to the higher summer temperatures throughout the U.S., there is a much greater tendency to propagate in the open or under-shade with the aid of mist. Only a very small percentage of plants are being grafted as a means of propagating some of the more difficult items, or where rapid reproduction is required. For example, a large proportion of the ferns are grown by this method. Frequent pruning and the selection of even batches of cuttings produce high quality saleable plants.

In the Sacramento Valley, California, I saw peaches, plums and almonds being produced on seedling understocks. The seed was sown in the autumn. During the following spring the seed germinated and by June had produced a pencil-thick stem. It was budded at this time after reducing the understock somewhat. Two weeks after budding, the understock is further reduced. By autumn the bud will have grown to about 6′ tall with the understock completely cut away above the inserted bud.

At Perry's Plants, where they grow bedding plants by the million, they had devised a seed-sowing rig. This enabled seed to be sown on a factory production line basis. The seed trays, filled with compost, were placed on a conveyor belt which took them under the sowing rig. The seed was sown through tubes, watered-in and covered with silver sand before continuing into a glasshouse for germination. The seed was pricked out by hand after this.

In the Pacific Northwest, Bruce Briggs was using pallets as large seed trays. He inserted cuttings into compost on the pallet at bench height and then moved the pallets by fork lift to an area for rooting. The pot liners were also put on pallets and placed under protection until established. The system involved a minimum of handling by hand but used a considerable number of pallets plus a forklift.

The Weyerhaeuser Company is a huge lumber company. They have an equally huge reforestation programme which is mainly from bare root seedling production. However, in some of the difficult establishment areas, tube-grown plants are used. These are produced in glasshouses by the million, by direct

sowing seeds into the tubes. The company is also doing considerable work on clonal selection, male and female, bud development (to produce more seed from their selected trees) and frost hardiness. Their aim is to increase the volume of timber produced by 100 percent.

It was evident that the large scale of production on many American nurseries gives them an ability to produce plants to a uniform size and high quality. Or could it be that their ability to produce plants to a uniform size and high quality enabled the companies to grow to the size that they are?

POTENTIAL EFFECTIVENESS OF GROWTH REGULANTS ON ORNAMENTALS

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A. The physiology of growth control
B. The types of chemicals with growth regulatory activity
C. Experiences with chemical control of flowering pot plants:
   i. Height retardation
   ii Production of cuttings
D. Experiences with chemical control of nursery stock:
   i Plant shaping
E. The commercial potential of growth regulator chemicals on ornamentals.

A. THE PHYSIOLOGY OF GROWTH CONTROL. The continuing advancement in the knowledge of the physiology and biochemistry of growth and developmental processes in the plant is enabling the plant scientist to explore the potential of chemical growth control with more purpose and precision and to evaluate the many biologically active compounds produced by the agricultural chemical industry. Such chemicals function by supplementing, inhibiting or interacting with the naturally occurring (endogenous) plant growth hormones. The hormone systems control not only developmental processes in plants such as germination, dormancy, flowering, and senescence but functioning within the constraints of the plant's genetic characteristics and under the influence of environmental factors they determine plant size and morphology.

The commercial production of plants in the "so-called" ornamental section of the horticultural industry involves plants of

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The commercial production of plants in the "so-called" ornamental section of the horticultural industry involves plants of

very different growth habit and a wide and physiologically complex range of genera with varying environmental response characteristics. But from the simplest seed-raised annual pot plant to the skillfully propagated exotic tree, there are fundamental chemical control systems which, with increasing experience and the correct "tools of the trade", we are able "in part" to regulate by the application of suitable synthetic chemicals.

An understanding of the types of endogenous plant hormones and their functioning in plants is helpful in the assessment of the potential of growth regulators.

Five groups of hormones are listed below. They are auxin, gibberellins, cytokinins, abscisins, and ethylene compounds. Some of their known functions are listed, but many of their functions are far from specific; frequently the physiological effect of a hormone is the result of its intercellular distribution and its relationship with other hormones at a particular site at a critical growth stage.

ENDOGENOUS PLANT HORMONES

AUXIN	Diverse functions including cell elongation, tropic movement, root differentiation, apical dominance, fruit set.
GIBBERELLINS	Stimulate cellular expansion; mediate in responses to day length and temperature; break dormancy, improve fruit set.
CYTOKININS	Promote cell division; delay senescence, stimulate growth of lateral shoots.
ABSCISINS	Growth inhibitor; involved in abscision of leaves and fruit; induced dormancy; increase cold hardiness; replace short day response.
ETHYLENE	Accelerates maturity and flowering; causes fruit ripening and abscision; causes leaf senescence; promotes lateral shoot development.

For the purpose of this paper let us take a rather simplistic view of some growth processes of horticultural importance.

Dormancy. The onset of dormancy in response to temperature or day-length seems to be correlated with changes in the level of GA. In birch, short-day conditions bring about a cessation of cambial activity within 2-3 weeks of the commencement of the short day. This change is preceded by a reduction in the level of gibberellic acid (GA). Dr. Loach at Glasshouse Crops Research Institute is investigating whether dormancy can be controlled in summer-propagated cuttings by application of GA.

Germination. This process would seem to involve the interplay of all the natural growth substances and, in some species, unspecified inhibitor substances which need to be leached from the seed before germination proceeds. The inhibition of germination of celery seed in the light by abscisic acid has been shown by Thomas (1975) to be alleviated by the application of cytokinins and to a lesser extent by gibberellic acid.

SYNTHETIC PLANT HORMONES

Group	Examples of chemicals	Trade designation
AUXINS	IAA; IBA.	Rooting hormones
	NAA: NAD; TIBA; CPA	Setting hormones
	2,4-D; 2,4,5-T	Herbicides
GIBBERELLINS	GA_3	Gibberellic acid/Berelux
	$GA_4 + GA_7$	Pro-Gibb 47.
CYTOKININS	N^6 benzyladenine (BA)	Verdan
	PBA	SD 8339
ABSCISINS	Abscisic Acid (ABA)	—
	(Morphactins)	(E Merek)

GROWTH REGULATOR CHEMICALS

Group	Examples of chemicals	trade designation
RETARDANTS	ACPC	Amo - 1618
	ACR 1158D	Alden
	Ancymidol	Arest
	Chlormequat (CCC)	Cycocel
	Chlorphonium	Phosfon
	Daminozide (SADH)	Alar/Kylar/B-Nine
	Maleic hydrazide (MH)	MH 30
BRANCH PROMOTERS	Dikegulac - sodium	Atrinal
	NC 9634	(Fisona)
	MB 25.104	(May and Baker)
	PP 528	(ICI Plant Protection)
	SD 8339	(Shell)
PRUNING AGENTS	A 820	(A M Marks)
	Aliphatic Alcohols + NAA	Tipoff
	Fatty acid esters	Off-Shoot-0
	UBI - P293	(Uniroyal)
ETHYLENE COMPOUNDS	Ethephon (CEPA)	Ethrel E.
OTHERS		
Antitranspirants	Polyvinyl resin	S -600/Clarital
	Phenylmercuric acetate (PMA)	-
	ABA	-
Defoliants	Ethephon + KI	Ethrel R.
Sprout suppressants	Tecnazene (TCNB)	Fusarex
	Chlorpropham (CIPC)	Several formulations

Fortunately, horticulturists by their interest and active involvement with trial chemicals at their latest stage of development have been able to quickly take advantage of those chemi-

cals which finally appear on the market, but there has been and will continue to be exciting and interesting chemicals which are withdrawn because of financial limitations.

B. CHEMICALS WITH GROWTH REGULATORY ACTIVITY. The range of chemicals available and undergoing development has, in recent years, considerably expanded. There are now sufficient types of chemicals to provide an effective armoury capable of attacking many plant functions. Below are listed the various groups of chemicals, with a distinction between the synthetic plant hormones and the chemical regulant types. Several of the chemicals exist as coded samples supplied for the development and evaluation purposes with their chemical identity unrevealed. Such secrecy creates difficulties in the scientific evaluation but they are included because they will be referred to in experimental reports. The list is long but in no sense should it be assumed that these chemicals exist because they have potential use on ornamentals. The sights of the chemical companies are set on the major world food crops and, with new chemicals, unless there is such a market outlet their marketability is in doubt.

Production of cuttings. Trials in 1972 indicated that chemicals could be successfully used on poinsettias and geraniums to stimulate branching and this presented the possibility of improving cutting production from mother stock plants. With poinsettias, the cytokinin SD 8339 applied at 750 ppm increased branching by 30%.

In 1973-74 the commercial significance of ethephon treatments to the production of geranium cuttings was tested. Treatments included ethephon applied as a drench of 300 ppm and as a spray of 1200 ppm; in addition, there was a combination of ethephon to improve branching and 2 sprays of 10 ppm GA to enhance extension growth. Records of cuttings taken are shown in Table 1.

Table 1. Cutting Production — Geraniums 1973/74.

Date	Ethephon Drench (300 ppm)	Ethephon Spray (1200 ppm)	Number of cuttings per plant Chlormequat	Ethephon + GA	Control
20 Dec.	9.9	11.8	8.8	12.3	10.2
6 Feb.	16.4	18.4	14.1	18.7	15.8
17 Apr.	29.8	29.5	27.2	33.4	29.5

The combined treatment was successful on the 3 cultivars and the increase in cutting production at the end of the season rep-

resented 13.3% overall, with 'Sincerity' showing a 20% increase.

C. EXPERIENCES WITH CHEMICAL CONTROL OF FLOWERING POT PLANTS.

Height retardation. Present production schedules for pot chrysanthemums and, to a lesser extent, poinsettias illustrate very well the integral part growth retardance can play in commercial horticulture and the perfection in control that can be achieved. Since the mid-60's it has become standard practice to retard the elongation on chrysanthemum shoots by using either daminozide or chlorphonium.

Cultivars such as the vigorous Anne types require 2 foliar applications of daminozide at 2,500 ppm or 750 g/c.m. chlorphonium mixed with the potting compost. Work has continued to find chemicals with improved activity and ancymidol was shown to be very effective in trials at the Lee Valley EHS in 1972. Satisfactory height control was achieved with either a drench of 5 ppm or 2 foliar sprays of 100 ppm ancymidol. Dr. Menhenett has found that the retardant Alden, produced by Magg, effectively dwarfed chrysanthemums when applied as a foliar spray at 100 or 275 ppm whereas the compost drench was effective at 10 mg a.i.

Chlormequat is very much part of the standard programme for height control of the Christmas poinsettia crop, either as a repeated foliar application of 1,250 ppm or a compost drench of 2,500 ppm. Work at the Lee Valley EHS showed that an ethephon drench (300 ppm) produced short plants without reduce the size of the bracts. Again, with this crop, ancymidol was extremely active at only 10 ppm.

The introduction of the seed-raised F_1 hybrids of pelargoniums highlighted the advantage in shaping the plant with retardants such as chlormequat, chlorphonium, or ancymidol with the consequential improvement in number of lateral shoots and flower numbers.

Height of Asiatic hybrid lilies can be controlled by compost drenches with chlormequat, ethephon, or ancymidol. Work at LVEHS and GCRI in 1972 reported that ancymidol was effective without reducing flower number.

There has been sufficient experience with the traditional retardant on the main lines of flowering pot plant for reliable recommendations of chemical and of rate of usage to be made. These are summarized below:

RECOMMENDATIONS FOR POT PLANTS

		Daminozide	Chlormequat	Chlorphonium	Ethephon	Ancymidol
Chrysanthemums	Sp.*	2 × 2500 ppm		—	—	200 ppm
	D	—	—	80 ppm	—	5 ppm
	I	—	—	750 g/m^3	—	—
Poinsettias	Sp.	—	3 × 1250 ppm	2	1200 ppm	?
	D	—	2500 ppm	—	300 ppm	10 ppm
Lilies	Sp.	—	—	—	?	?
	D	—	25,000 ppm	?	250 ppm	5 ppm
Pelargoniums	Sp.	—	—	—	—	—
	D	—	2,500	125 ppm	300	50
	I	—	—	1200 g/m	—	—

* Sp. = Foliar Spray D = Compost Drench I = Compost incorporation

In 1975, Cathey published a comprehensive report on the response of 88 species to 5 different growth retardants. In addition to flowering pot plants he included foliage plants, bedding plants, shrubs and trees. The number of species responding to each of the chemicals is shown below:

RESPONSE OF ORNAMENTALS TO RETARDANTS (CATHEY 1975)

Chemical	Year of introduction	Number	Species response
ACPC	1949	5	6
Chlorphonium	1958	12	13
Chlormequat	1960	21	24
Daminizide	1962	44	50
Ancymidol	1970	68	77

Of the 5 chemicals, the newest, ancymidol retarded 77% of those plants tested and showed the widest response spectrum. Daminozide was effective on 50% of the species. Only species of chrysanthemum, rhododendron, phaseolus and salvia responded to all 5 chemicals. None of the conifers, including cypress, juniper, redwood, and yew showed any visual response to the chemicals. Members of the rose family were another group with limited sensitivity to growth retardant type chemicals.

Rooting. Root differentiation was shown by Thimann and Went (1934) to be stimulated by auxin and now the application of a "rooting hormone" has become part of standard horticultural practice. In the propagation of plants from cuttings the presence and proportion of leaves and flower parts on treated cuttings can greatly influence rooting effectiveness, indicating that auxin is not exclusively responsible for root differentiation. The cytokinins may have a regulatory function.

Extension growth. Both auxin and the gibberellins participate in the growth of plant shoots and stems and promote cellular elongation so producing internode extension. It has been

demonstrated that the application of GA will stimulate such growth. In tree species vigorous shoots are characterised by a higher auxin content. Retardation of extension growth can be achieved by the application of synthetic chemicals which interfere with the synthesis of auxin or gibberellin.

Apical dominance. Axillary bud development is suppressed by auxin which is synthesised in the terminal apex of the shoot. Removal of the site of synthesis by pinching or pruning techniques releases the control over the growth of lateral shoots, at least temporarily. Usually the growth of a limited number of laterals from axils towards the top of the shoot occurs and these, in turn, regulate the development of laterals further down. The angle at which branches grow in tree species is also auxin-controlled and branches are known to grow more vertically if the apex is removed. Cytokinins move from the root system and are considered to have a stimulatory effect on branch production. This function of endogenous cytokinins has been exploited recently by the use of a range of synthetic chemicals to promote branching.

D. EXPERIENCES WITH CHEMICAL CONTROL OF NURSERY STOCK. With pot plants the main requirement is to control height; with container nursery stock the objective in the use of growth regulant chemicals is to improve the overall shape of the plant, in particular to encourage controlled growth of lateral shoots, to stimulate bud initiation and to reduce production time and labour input. The amount of experimental work with growth regulants on hardy ornamentals in the UK is sparse and of scattered origin. Work by Sachs and Maire (1967) in USA indicated that maleic hydrazide and daminozide were effective as retardants on pyracantha and cotoneaster species. In the early 1970's there was work with TIBA, PBA, and ethephon; the latter two chemicals were found to promote branching of roses. Further work was done with ethephon and formulation was marketed for use in glasshouse roses to improve basal branching. Another area of work was with the chemical pruning agents based on fatty acid derivatives. These emulsions, when applied to plants with buds at a critical stage of development, killed the meristematic tissue. This work resulted in the development of Off-Shoot-0 and Cathey in 1970 published a detailed list of species response and optimum dosage rates.

Bud Initiation. Work by Margaret Scott has been in progress by Efford EHS for the past 4 years on the combined use of high nitrogen and phosphate, with chlormequat treatment, to promote budding in camellias. Two compost drenches of 3000 ppm chlormequat applied during June and July ensured maximum budding in most seasons. Treatments on rhododendrons has been more variable in effect.

Shaping (*Pruning/Pinching*). In 1974 Scott reported on a trial where 2 branch promoters, SD 8339 and NC 9634, had been applied to 1-year-old plants of *Ilex aquifolium*. The application of 5000 ppm NC 9634 in June increased the number of shoots per plant by 50%. At this time this chemical was being extensively tested as a means of improving feathering of maiden fruit trees. Dr. Quinlan reported that at East Malling Research Station that feathering had been increased on 'Comice', 'Bramley' and 'Discovery'. Encouraging results were also obtained on 'Bramley' with the experimental chemicals PP 528, UBI-P 293 and Atrinal. An indication of the longer term potential of trees chemically shaped is obtained from the records taken at East Malling with some trees of 'Bramley Seedling' treated in the nursery in 1971 with the treatments repeated in the orchard in 1972 and 1973. Table 2 shows that in their second cropping year the hand-pruned trees produced fewer flower clusters and fewer fruits than the sprayed trees.

Table 2. EMRS — 1975 Results From Tree Shaping Experiment

	Hand Pruned	NC9634	Off-Shoot-0
Flower clusters per tree	46.8	100.3	88.2
Number of fruits per tree	26.2	44.9	53.5
Crop wt (kg) per tree	5.12	8.60	10.72

As well as the possibility of stimulating lateral growth, Dr. Quinlan's work has shown that unwanted side-shoots can be controlled with the chemicals A 820 and Tipoff applied in May. This work on fruit was encouraging and the results suggested that possibly container-grown nursery stock could be effectively shaped by using this relatively new group of branch promoter chemicals and pruning agents.

Another interesting chemical is under development by Maag of Switzerland. The activity of this compound, dikegulac-sodium (Atrinal) was described in "Nature" (13 November 1975). More recently a comprehensive list of recommended usages has been issued and indicates the potential of this chemical for shaping hardy ornamentals.

Trials were conducted in 1976 by the ADAS Plant Physiology Unit, in conjunction with Horticultural Advisers in Worcester and at Luddington EHS to compare the three types of growth regulants (retardants, branch promoters, and pruning agents) with manual pruning on a range of nursery stock subjects, with the objective of improving plant shape. The treatments applied are shown below:

NURSERY STOCK TRIAL — 1976. Treatments:

Type	Chemical	Concentration (ppm a.i.)
1. Retardant	Daminozide	5,000
2. Branch Promoters	Atrinal	1,000
3. Branch Promoters	Atrinal	4,000
4. Branch Promoters	NC 9634	2,000
5. Branch Promoters	NC 9634	5,000
6A Pruning Agent	Off-Shoot-0	42,000
6B Pruning Agent	UBI - P293	20,000
7. —	Hand Pinched	—
8. —	Control (Untreated)	—

Treatments were applied as foliar sprays on 13 and 26 May to cuttings rooted in autumn, 1975, and grown on in polythene tunnels. The preliminary results of these trials are very interesting; of the three types of regulants, the retardant daminozide has not been effective, and the pruning agents have given variable results, but the branch promoters stimulated branching in at least 7 subjects. Growth asessments were made 8-10 weeks after application. The results for *Forsythia* and *Cornus* are shown in Table 3.

Table 3. Use of Growth Regulants for Shaping Nursery Stock. 1976.

	1. Daminozide 5000 ppm	2. Atrinal 1000 ppm	3. Atrinal 4000 ppm	4. NC9634 2000 ppm	5. NC9634 5000 ppm	6. Off-Shoot-O 4.2%	7. Hand Pinching	8. Control
Forsythia 'Lynwood'								
Shoot number	3.1	8.2	13.0	7.7	7.8	3.2	5.2	2.7
Height, cm	53.4	35.8	29.5	42.9	32.7	48.5	47.3	54.5
Cornus stolonifera 'Flaviramea'								
Shoot number	4.1	12.8	15.4	6.1	8.1	—	6.9	3.4
Height, cm	42.0	29.5	31.8	51.3	48.1	—	40.6	47.8

Atrinal stimulated most branching, with a substantial decrease in overall height of the plant, but there was some interveinal yellowing of the terminal leaves. NC9634 also improved branching. Other subjects showed an improvement in shape at this stage of growth, including *Euonymus fortunei* 'Gracilis' (*E.f. radicans* 'Vareigata'), *Prunus laurocerasus* and *Weigela florida*. Further assessments will be made during the season in order to ascertain whether there are any permanent side effects, foliage markings, or retardation of growth which affect plant quality. The early indications are that Atrinal is an exciting chemical which, with the necessary refinement to timing and rate of application, has the potential to produce the required response. It seems likely that this compound will appear on the UK market as a regulant for retarding and thickening hedgerows in late 1976 and so its marketability would seem assured, thus justifying more detailed trial work.

E. POTENTIAL EFFECTIVENESS OF GROWTH REGULATOR CHEMICALS. Production of Belgian Indica hybrid azaleas is an example of effective use of growth regulant chemicals; the shaping of the plants is achieved by chemicals such as Off-Shoot-0 or Atrinal and bud initiation is encouraged by the retardant Daminozide. There is even recent work which suggests that the cold treatment required to break bud dormancy can be replaced by GA treatment. Such precision is possible with a crop that is produced under very controlled environmental conditions. There is concern that such a reliable effectiveness can be generally achievable on nursery stock. Growing techniques show much variation, e.g. type of cutting material, propagation schedules, compost, nutrition, whether grown under polythene or in the open, whether grown fast or slow. These factors are critical to the plant in its response to exogenously applied chemicals and can effect the uptake and mobility of the chemical.

I am optimistic that on those species where these chemicals are shown to be of real advantage, production systems will be planned for maximum plant response.

Certainly the range of chemicals under development gives the plant scientist flexibility in chemical control. The newest group of branch promoters including NC 9634 and dikegulac-sodium has exciting possibilities. It would seem from the trials to date that the objectives in using growth regulators are now within reach. It is as well to end by restating those objectives for containerised nursery stocks:

1. To improve plant quality
2. To produce a good quality plant more quickly
3. To replace labour intensive cultural procedures for plant shaping with chemical control techniques to reduce production costs.

These objectives are as important to the "cheap" lines produced in quantity as they are to the exotic plant. Chemical control should be used only if these objectives can be reliably achieved at reasonable cost.

THE PROPAGATION OF UNDERSTOCKS FOR HAMAMELIS

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Abstract. *Hamamelis* species can be rooted from cuttings in high numbers but losses in the young plants can be heavy during the first winter. Trials indicate the importance of taking cuttings early, inducing good growth, and avoiding high fertility levels in growing on composts. *H. vernalis* promises to be easier to propagate than *H. virginiana* and to be compatible as an understock for *H. mollis*.

The usual understock for grafting *Hamamelis mollis*, *H* × *intermedia*, *H. japonica* and cultivars is *H. virginiana*. In our experience the importation of this understock is expensive and the supply is uncertain. This focused our attention on the possibilities of home production from cuttings.

Propagation of *Hamamelis* from cuttings is not mentioned by Sheat (1) and has been unsuccessful in Canada (2). Fordham and Mezitt (3) referred to the successful rooting of *H. mollis* from softwood cuttings in June, followed by cold storage.

At Kinsealy observational trials have been carried out on the propagation by cutting of *H. Mollis*, *H. virginiana* and *H. vernalis*. In our experience the difficulty in raising plants of this genus is not associated with the rooting of the cuttings, but with their treatment subsequently, for overwintering losses in the first year can be high. The young plants may even come into leaf in spring, only to collapse and die when it might be assumed that they were safely started on a new season's growth. Experience indicates that similar losses in other genera can be associated with excess of fertilizer salts in the soil, but with *H. virginiana* S.C. levels of 31-60, well below the critical figure of 100, have not solved the problem.

Undoubtedly rooted cuttings of *Hamamelis* that do not make extension growth before winter are bound to fail. At Kinsealy overwintering mortality in such plants is always high. We, therefore, take the cuttings as early in spring as possible. Indications so far are that *Hamamelis* mother plants do not respond readily to forcing by sun heat in a plastic house, a technique that has solved similar problems in the propagation of *Magnolia* and *Acer*. More work, though, is needed on this aspect.

To date we have concentrated on taking the cuttings from outdoor plants as soon as the shoots are large enough to handle. Under our conditions this is during the second half of May. At this time the young shoots of *H. virginiana* are only 3-4 cm

long, with 3-4 leaves unfolded. Basal cuttings are taken, i.e. cutting through the junction with the parent stem.

The prepared cuttings are immersed momentarily into a solution of Captan (1 tablespoon per gallon of water) as a phytosanitary measure. A proprietary rooting powder containing 0.8% IBA is applied to the bases of the cuttings, which are then inserted into a substrate of moss peat only, in a mist unit.

This procedure is based on the results of preliminary trials carried out in 1968 (Tables 1 and 2).

Table 1. Rooting of *Hamamelis* in 3 substrates.

Species	Substrate	Percentage rooting
H. virginiana	Moss peat	75
H. virginiana	2 Peat, 2 sand	60
H. virginiana	2 Sand, 1 peat	55
H. mollis	Moss peat	90
H. mollis	2 peat, 2 sand	50
H. mollis	2 Sand, 1 peat	55

In subsequent seasons the use of moss peat and 0.8% IBA powder has continued to give good results and available plant material has been used to investigate the more urgent problems of the treatment of the young plants during their first season.

Table 2. Effect of IBA on *Hamamelis* cuttings.

Species	IBA Treatment	Percentage rooting
H. mollis	None	75
H. mollis	0.2%	62
H. mollis	0.4%	87
H. mollis	0.8%	100
H. japonica 'Zuccariniana'	None	37
H. japonica	0.2%	62
H. japonica	0.8%	64

In our early attempts, losses were directly attributable to the use of too rich a compost. If the rooted cuttings make little growth during the rest of the season, fertilizer salts can accumulate to excess levels, hence the importance of taking cuttings early and inducing good growth before winter. In 1975, (our most successful results to date) 100 cuttings of *H. virginiana* inserted under mist on May 20th had rooted 100% by June 24th. These were potted up in three soil mixes and kept on the glasshouse bench. By the following April, 70% had survived in peat with John Innes Base (¼ lb per bushel), with a mean height of 14 cm. Better mean growth (20 cm) was recorded in peat with Osmocote 14:14:14 at 2 oz per bushel, but

survival was only 43%. Poorest were plants in John Innes Potting Compost (mean height 9.5 cm 37% survival). All treatments, however, showed some plants with dieback of the tips.

While a 70% survival rate in *H. virginiana* is encouraging, attention should be drawn to the more promising results obtained with *H. vernalis*. It was noted that this species came into growth earlier and produced more vigorous shoots, so that larger cuttings (7-8 cm) could be taken sooner than from *H. virginiana*. Results of cuttings taken on two dates are shown in Table 3. These cuttings were grown on in the peat and Osmocote 14:14:14 mix as for *H. virginiana*. Dieback was noted on the plants surviving into spring.

Table 3. Propagation of *H. vernalis* from cuttings.

Date inserted	Date lifted	Percent rooted,	Percent survival	mean ht (cm)
7/5/75	24/6/75	80	80	28
29/5/75	25/7/75	75	66	27

These plants were sufficiently developed after one year from the cuttings for a preliminary trial on the grafting of *H. mollis*. Eight plants were grafted on March 5th. The scions then were dipped into paraffin wax and placed on the open bench. Union was successful in four grafts. The remainder of the stocks are being grown on for August grafting. Growth was vigorous on a capillary bed inside a plastic house; indeed, so much so that the plants should be moved outside in late spring if they are not to be over-large by grafting time.

Several attempts have been made at Kinsealy to raise *H. mollis* from cuttings. Rooting has been good, ranging from 60% to 100% in different seasons. This species, however, has been subject to heavy overwintering losses, hence our continuing interest in the propagation of the understocks. Further means of improving this technique to be considered include the use of extended lighting to improve growth. Trials on holding the young plants in cold store for the winter have not given good results under our conditions.

Mention should be made of the remarkable growth attainable in *H. mollis* when raised from seed. This is the only species observed to ripen fruit regularly under conditions near Dublin and, though the seed requires stratification for two winters, the plants can be over 3 ft tall at the end of their first growing season.

Thanks are due to F.J. Nutty for technical assistance in these trials and to the National Botanic Gardens, Glasnevin for supplying cutting material and seed.

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THE SELECTION AND PROPAGATION OF DWARF CONIFERS

H.J. WELCH

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Turning first to the selection of dwarf conifers by the purchaser:- My experience at flower shows is that, (having disposed of queries as to whether my dwarf conifers are bonsai, or house plants, or ferns; or even, on one occasion, cacti) the first serious question raised by visitors always is "How big will it grow"?

This is so basic to the production and sale of dwarf conifers that it is a matter on which I feel we, as nurserymen, should be able and willing to give the public much clearer guidance than we sometimes do. First and foremost we must endeavour to put over the fact that there is no simple answer to this apparently simple question; the concept of "ultimate size" just does not apply to plants which continue to grow throughout their long lives. Although the term "Dwarf Conifers" is too well established ever to be ousted from the language, one fact I believe we must get across is that they would be more accurately described as "slow-growing conifers" in that they are dwarf only because their rate of growth is less than is normal (sometimes it is very much less). After a few years taken to settle down in their new home, the dwarf conifers will begin to increase in size, each at its own chosen rate, and that they will continue to do this steadily for a hundred years or more.

The customer buying dwarf conifers usually has a more-or-less definite idea of the size of the plant he has in mind for his particular situation, but he is willing neither to wait many years for a very slow-growing plant to mature to his chosen size nor to pay the price of a suitably ancient specimen (even if you have one on the nursery) so he is compelled to accept a compromise; he must plant a cultivar that is obtainable at a size to give an acceptable immediate effect (and at a moderate price)

LITERATURE CITED

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and be willing to sacrifice his tree or move it elsewhere when, as is bound to happen, it outgrows its welcome in that particular spot. The point I am trying to make is that we have a duty to explain this situation to the customer. In place of the "ultimate sizes" concept, we must attempt to get him to grasp the idea that (to secure the effect he wants at that spot in his garden) he has to make use for a limited period of years of a conifer that will, inevitably, get too big for him in time. Yes, certainly he may be told that he may then move it elsewhere, but "In That Spot" it will have had a "useful life" of, say 8 to 15 years. Only by making this clear can we honestly (and in the long run profitably) continue to sell *Chamaecyparis lawsoniana* 'Ellwoodii' as a dwarf conifer.

But even when he has grasped this new principle, i.e. the connection between size and time, or as I put it the "useful life" concept, the customer still needs our guidance, and for this I believe that some acceptable form of classification in the trade is required. It is probably not of sufficient importance to justify attention by the august bodies who establish standards and codes of practice, but if some simple classification were to come into general use it would be of considerable benefit both to the nursery trade and to the general public when purchasing their dwarf conifers. There are several possibilities. Quoting an annual rate of growth is misleading, since growing conditions can vary so much. I see that Adrian Bloom in his book "*Conifers for your Garden*" grades the plants he describes according to their likely height after 10 years, and as a basis for adaptation, the following size and habit code has been used in my own catalogue for many years.

A. Slow-growing but eventually of tree height.
B. Slow growing 10′ to 15′ } After
C. Slow growing 5′ to 10′ } many
D. Slow-growing 3′ to 5′ } years
E. Low buns & bushes growing 3′ or less.
F. The real pygmies.
V. Columnar
W. Pyramidal or upright.
X. Globosa, rounded.
Y. Spreading, wider than high.
Z. Prostrate, trailing or pendulous.

Other than this, on the subject of selection of dwarf conifers by the customer there is not much more I can say. Since it is practicable to provide pockets of modified soil or a suitable micro-climate for a small plant where it would be impossible in the case of a large tree, the customer can be told that he has more latitude with the dwarf forms, but broadly, as regards soil requirements, hardiness, etc., they follow the normal arboreal forms of their respective species and the advice the customer needs (such as that the *Juniperus* and *Taxus* are the best genera for chalk; that the golden forms need full sun, and so on, will be the same).

The selection of dwarf conifers by the nurseryman divides itself into two parts. Firstly, there is the question of how many cultivars he wishes to carry and include in his list, and since this depends entirely upon the area he is in, the type of trade he does and other local circumstances, no guidance from me is possible. Since in my own collection I have over 1000 cultivars, each of which I propagate in small numbers for my own very specialized market, there is almost unlimited scope, but most propagators will limit themselves to a very much smaller number. Fortunately, the cultivars most in popular demand are those that are most easily propagated and, unless a nursery intends to become known as a specialist in dwarf conifers, it is usually sound economics to limit the range to these forms, since in a general retail outlet the less well-known cultivars are apt to hang.

On the subject of the selection of new cultivars I would like to put in a plea for caution and restraint, since (along with roses and many other groups of garden plants) there are already many more cultivars than we have need of. Mutations turn up quite regularly in the seed-beds. Usually the slow starters are regarded as runts and are discarded, but occasionally (too often in my contention) one of them — the seedling with a difference — will be allowed to grow on and is eventually propagated and introduced as an exciting new dwarf conifer. Or a bud mutation will be noticed on an existing cultivar and be hailed in the same way. Since seedling variation invariably tends to become less as the plant matures and since bud mutation has the same tendency to disappear, we are left, in time, with far too many, much too similar cultivars. A well-known example of this would be the numerous golden named forms of Lawson cypress. No doubt, when introduced, each of these was distinctive, but now, 25-50 years later they are virtually indistinguishable. Similarly, *Thuja occidentalis* is prone to produce attractive globose plants from seed and of these there are so many well-tried cultivars with new forms that I have received from, for example, Denmark, Poland and the United States, seem unlikely in the long run to turn out adequately distinct from or improvements on the old cultivars.

A current problem arises, I believe, from the sporting habits recently developed by the popular cultivar 'Ellwoodii', although now quite old enough to know better. 'Ellwood's Gold', 'Ellwood's White' and 'Chilworth Silver' (respectively golden yellow, white variegated, and silvery-grey) are each quite distinctive, but I *am* dubious about the spate of allegedly blue forms that are appearing in different parts of the world.

Of these, I already have 'Blue Gem', 'Blue Surprise', 'Blue de Mantes' and 'Blue Cone' and I believe there are others. Even

if we are spared 'Blue Down', 'Blue Peter' and 'Blue Funk', I am afraid we are in for problems in identification later on, since grown side by side, I find them barely distinguishable. Amongst the rarer species also, the tendency is the same. Just as every seedling could be a worthwhile new clone but every one certainly isn't, so each witch's broom discovered on a Norway spruce or a Scotch pine cannot be expected to produce a distinctive new dwarf conifer. We already have about 80 named dwarf spruces and nearly 30 dwarf pines in these particular species and — by any standard — these are enough or more than enough.

With present day techniques and equipment it is quite an easy matter to build up worthwhile commercial stocks of a new dwarf conifer before the original mother plant itself is old enough to have demonstrated its characteristics when mature — these being sometimes quite different from its behaviour as a young plant, so there is real need for restraint and patience before new forms are introduced to the trade which will add one more name to our lists but no more beauty to our gardens. If a long period of growth is considered necessary before an arboreal conifer is regarded as justifying recognition as a new cultivar (this is usually the case, since normally any selection of this kind is made from a mature tree) how much more important it must be in the introduction of supposedly new dwarf forms whose appeal lies in some deviation that may consist only of juvenile qualities that it will eventually outgrow, or a mutation that may prove to be unstable. In either such case the apparent value is misleading and premature action will only lead to confusion and trouble in the future.

On the subject of propagation I hardly think that the organizers of this conference can seriously think that I can be capable of saying anything fresh, partly because the propagation of dwarf conifers differs only in detail from the propagation of conifers in general and partly because the art of plant propagation has been exercised for so long that it is a matter of serious doubt whether (excepting only the operating instructions supplied with new technical equipment) there is anything really new on the subject that can be said. I have not seen it, but I understand that an old manual dating back to medieval times and written in Arabic, is known which deals with all phases of plant propagation in considerable detail, and relevance today, and I recently myself became possessed of a work entitled "*The Propagation and Botanical Arrangements of Plants and Trees*" by a certain John Abercrombie (described as the author of "Everyman His Own Gardener") published in 1784, which covers the ground as completely as any modern manual that I have ever seen.

I do not need to discredit the idea that dwarf conifers can be propagated from seed. Dwarf forms, being individual variants, seldom set seed, since nature preserves her species by making her freaks sterile, and if and when they do the progeny usually revert to what is normal to the species. Many customers, however, encouraged by certain operators selling conifer seeds at provincial flower shows, possess this idea and every opportunity should be taken to disabuse their minds thereof.

Although propagation by cuttings is the principal method in commercial use today, it is the method upon which I shall have the least to say, for the reason that the technique for the dwarf forms differ only marginally from the propagation of conifers of normal size. Our cuttings, rather obviously, usually are smaller than normal. Success with cuttings depends so much on the interplay of many factors that anyone attempting to lay down rules is asking to be contradicted, but I personally have never had any success with the very small cuttings that some successful plant propagators delight in. In a mixed batch, with me, invariably the large cuttings do best, so I aim to use cuttings as large as possible — subject to the selection of suitable material. I make this a strong provison, because with dwarf conifers it is a matter of vital importance. This is because the use of strong cuttings taken from leading shoots on vigorous branches will often produce coarse plants quite out of character. Cases of this kind are *Chamaecyparis pisifera* 'Squarrosa Intermedia' and *Chamaecyparis lawsoniana* 'Forsteckensis'. Such congested cultivars will only remain so if cuttings are taken from bunchy, congested side-growths and the loss of the desired dwarf characteristic is accentuated if this selection of unsuitable propagating material is continued again and again through further cutting generations.

To a greater or less extent this must be true of all the dwarf forms, so we are faced with the need for compromise here, since the two needs, the need on the other hand for producing a commercially viable produce and the need on the other hand for preserving the dwarfness that is the main attraction of the plants are opposed to each other. This becomes increasingly important the more dwarf the cultivar, until when we come to the very diminutive forms they become irreconcilable. A tiny gem of this kind is usually written off as "not a nurserymen's plant" and such are really only of interest — if worth attention at all — to the very dedicated specialist.

Grafting is another subject important in a wider context than dwarf conifers and one to which I shall return later, so here I need only make a few comments. Many of the plants of the rarer species and cultivars, particularly the dwarf pines that are produced in this way will later be grown on by the cus-

tomer, if not as Bonsai, at least as specimens in pots. This must be borne in mind, since customers for this class of tree are very choosey; the graft itself is impossible to disguise entirely but if it is unsightly the tree largely loses its appeal. I aim to make a relatively long side graft, since this gives a much stronger union in a mechanical sense during the first critical two or three years during which the graft is much weaker than it appears, and this together with careful matching of the scion and rootstock diameters and neat workmanship reduces the unsightliness of a graft to a minimum, especially if (as should always be the case) the graft is kept as low, as near the surface of the soil as is practicable. Here the size of one's fingers seems to be the limiting factor, this being obviously a case where Nature has not observed sex equality. When these points are watched the long joint-line running parallel with the trunk is not conspicuous, the scar where the rootstock has been snagged heals readily (and in many cases is hidden by foliage) and, if the base of the graft is at all unsightly, it may be dropped below the surface of the soil.

I find that very small scions seem to have, in general, less chance of success than those of normal size. Because of the small amount of annual growth made by the slower growing cultivars this necessitates the use of older wood. In any case making the graft on second year wood means not only that the maiden will have a branch structure one year older, it will start much nearer the surface of the soil, and this is regarded as a great asset for the pot culture I have mentioned. Because of the paucity of material in the very slow-growing forms this may not always be practicable.

HARDY ORNAMENTAL STOCK BEDS

DOUGLAS ANDERSON

Darby Nursery Stock Ltd.
Thetford, Norfolk

In 1962 Darby Nursery Stock Limited, started to establish a wholesale production unit specializing in container grown shrubs and conifers. Before this date, the company was concerned with the production of certified soft fruit stocks, mainly strawberry plants, blackcurrant bushes and raspberry canes for commercial fruitgrowers.

It soon became apparent that large quantities of propagation material were needed and, at that time, unrooted cuttings of deciduous shrubs were not easy to obtain from trade sources although rooted conifer cuttings and, to a limited extent, unrooted cuttings could be obtained mainly from the continent.

It was decided to plant up stock beds to ensure a good supply of cutting material. It should be pointed out that no ornamental field-grown stock was produced, which might have yielded suitable material.

We already had some 20 years experience in the establishment and maintenance of blackcurrant stoolbeds, for the production of hardwood cuttings.

In this particular case, stock beds are essential for the following reasons:

(1) Maintenance of health standards laid down by the certifying authority.

(2) Ease of inspection.

(3) Production from the right type of propagation material.

(4) Ease of management; e.g. pest and weed control; cutting collection.

(5) Makes the indexing of stock plants possible and, by carrying index number of parent with the cuttings, it is possible to rogue out young bushes should the parent prove unsatisfactory, or vice versa.

The first ornamental stock bed of 1½ acres was planted in spring, 1967. Approximately 50 plants of every shrub and conifer we listed at that time was planted out 6′ apart and 2′ between the plants, the object being to form hedgerows in the field. The planting distance, in the rows, on reflection, proved to be too narrow and in 1972, a further 3½ acres were planted at 6′ × 3′.

The rate of growth varies tremendously from cultivar to

cultivar and, as time passes the rows of plants must be tailored to meet requirements. Some cultivars may need to be increased, some decreased, depending on the yields of cuttings. The maintenance of the stock beds is fairly straightforward. The important points to bear in mind are as follows:

(1) *Irrigation.* The provision for irrigation facilities to supply water, particularly in spring and early summer is essential. The production of cuttings can be delayed if water is short.

(2) *Weed Control.* On most soils, Simazine @ 2 lbs per acre or Casoron, 110 lbs per acre, will deal with most weeds. However, care must be taken to avoid the build up of resistant species. Failure to adequately control weeds can lead to expensive hand-weeding operations. It is most important to plant on clean land.

(3) *Pest and Disease Control.* If good quality disease-free material is to be produced, susceptible species must be sprayed, as regularly as possible. The main pests encountered are aphids, red spider, and mildew.

(4) *Feeding.* A general fertilizer is applied (14:6:20) by hand along the rows in early spring just before growth starts, at approximately 2 oz/yard run; i.e. 3 to 4 cwts per acre. This is important, as it is necessary to maintain the stock plants in vigorous growth. However, care should be taken to avoid excessive nitrogen as this can lead to the production of the wrong type of cutting material.

(5) *Pruning.* Stock plants of deciduous plants and some of shrubby evergreens are pruned fairly hard, to a basic framework during the dormant season. Some plants only require a light trim, as not all plants respond to severe pruning. The less vigorous and low growing plants usually receive sufficient pruning as cuttings are removed. Pruning is important to encourage the production of vigorous growth and to try to promote juvenility in shoots, which seems to be so important in the successful rooting of cuttings.

(6) *Siting.* Whilst nurserymen do not usually have much choice regarding the site for a stock bed, obviously the nearer to the propagation department the better. It is important that the propagator can keep a close watch over the stock, and that cutting material does not have to be carried long distances in hot weather.

The following are some of the advantages we have found from having stock beds:

(1) Large batches of cuttings can be made available at one time, thus avoiding the inconvenience of having to root several batches at different times.

(2) Cuttings can be gathered at the optimum time and, if necessary, by unskilled labour. If cuttings are collected from young stock or saleable plants, it is necessary to use a skilled staff member who can be trusted to remove cuttings carefully. This is also time consuming and it is difficult to supply sufficient material to a team of people on this basis.

(3) With plenty of material available, grading can be rigorous.

(4) The stock bed can be managed to produce the right sort of material and trials and experiments and indexing of parent plants are easier to carry out.

(5) It is possible to eliminate rogues, or plants with undesirable characters, e.g. poor shape or colour, poor rooting qualities.

(6) If improved forms of certain plants become available, a comparison can be made with existing stock and replacements made if necessary.

(7) Protection can be provided for plants subject to winter damage. e.g. straw covering.

(8) Plants requiring forcing techniques to produce etiolated material can be covered with polythene structure.

Whilst appreciating all the advantages of having a stock-bed, there is, as always a price to pay. Firstly, the land must be available, as the stock bed will be permanently occupied. Secondly, there are costs involved in its establishment and maintenance.

It is always difficult to compare costs with other nurserymen in any meaningful way, as the costs incurred not only vary considerably from season to season, but also it depends on the system of management on each individual nursery.

However, the following figures will perhaps give an appropriate indication of the cost of maintaining a stock bed:

Hardwood Cutting Stock Bed (Blackcurrant bushes)

Planted: Spring, 1972
Area: Approximately 3½ acres
Number of stock plants: 5,250
Cutting yield per annum (8" cuttings): 250,000
Labour input in 1975/76 season: £604.00
Assuming labour to be 40% of Total Cost, then Total Cost is £1509.00
Therefore, cost of cuttings = 1509/250 = £6.00/1,000

If selling price of one-year-old bushes = £99.00/1,000, then cutting cost is 6% of selling price. Please note, in this season, the majority of costs were incurred in spraying and cutting down. No account has been taken of the preparation of cuttings

or establishment costs.

Softwood cuttings (Ornamental shrubs and conifers)

Planted: 1½ acres 1967, 3½ acres 1972.
Number of stock plants: Approximately 15,000
Yield of cuttings: Minimum 5,000,000 — many more available, if required.
Labour input in 1975/76 season: £1988.00 (say £2,000.00).
Assuming labour to be 40% of Total Cost, then Total Cost = £5,000.00.
Therefore, cost of cuttings = £5,000.00/500 = £10.00 *per* 1,000.
If average selling price is 0.65p per plant (container grown) i.e. £650.00 per 1,000.

Then cutting cost = approximately 1½% of selling price. *Please note, in this particular season, just over 50% of costs* were incurred in hand weeding, due to the failure of residual weedkillers to act in dry soil conditions.

No account has been taken of cost of collecting cutting material or establishment costs. The above cost would be greatly reduced if we could make use of all the cuttings that are now being produced.

Whilst these costs may be of some interest to you, we did not decide to plant our stock beds on the basis of figures. The decision was made because we could see no other way to produce good quality material in quantity that was easy to collect. *We are still at the beginning of our understanding of stock* plant management and, in time, I am sure the treatment given to stock plants will become much more important in ensuring that the material produced will propagate more easily.

PRODUCTION OF PLANTS FROM SEED

DENIS FORDHAM

Oakover Nurseries
Ashford, Kent

The subject of raising trees from seed is rather a lengthy one, I therefore, intend to talk about production generally rather than about one particular crop or plant with reference to the methods being used at Oakover, producing seedlings in raised seed beds covered with grit.

Before raising plants from seed one might ask oneself, what are we trying to achieve? This is the key question, the answer to this is to produce plants that will fulfill the market's requirements, *i.e. large one-year plants suitable for stocks or wide* lining, for containerization, or for close lining to produce a 1 +

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1 seedling. Since all the requirements for these purposes are different it is no good using the same method of growing to try to achieve this, it does not work; e.g. *Acer platanoides* seed sown in early March at about 200 per square yard will produce a large seedling at the end of the season as compared with sowing much later at a greater density, producing more smaller plants per square yard. This can only be accomplished by understanding each crop in question and using this knowledge to achieve what is required. It is acquiring this knowledge slowly that causes us to continually re-think and modify systems of production for particular plants each year.

From the start one must pay attention to detail, from the arrival or collection of seed, storage, stratification or treatment required, sowing time, plant population, soil conditions, water and nutritional requirements, pest and disease control, and lifting; all are equally important and I hope to highlight parts of these in the time available.

SEED HANDLING AND TREATMENT

This is one of the most important stages; bad handling in storage and treatment can result in rapid loss of viability and, of course, this cannot be restored. This is rather complex, the requirements vary considerably from plant to plant in the type of dormancy that may be present, e.g.:

1. Physical (hard seed coat)
2. Impervious seed coat
3. Chemical inhibitors
4. Immature embryo
5. Immature hypocotyl

As well as the life expectancy of the seed, I shall quickly mention a few ways we handle and treat our seed.

Handling. Riddling. With large seeds, e.g. oak, horse chestnut and sweet chestnut, these are all riddled to remove the small seeds that have less energy and would normally be suppressed and produce a second rate seedling.

Floating. Certain seeds, e.g. beech, horse chestnut and *Prunus avium*. When these are placed in water the empty and dead seeds float and the live sink.

EXTRACTION

1. Fruits containing seeds, e.g. *Sorbus*, *Malus* and *Pyrus* are pulped down and washed through various sizes of sieves to separate the seed.

2. Dry seed e.g.:

A) Legumes are dried to cause the pod to twist open and free the seed.

B) Birch. Collected catkins are air dried, broken up and put through sieves.

C) Norway maple and sycamore (*A. pseudoplatanum*) are collected green and air dried.

TREATMENT

1. **Traditional stratification.** A lot of seed (because we do not yet use acid) are stratified in the traditional manner using a peat/sand medium for one or more season, e.g. *Fraxinus excelsior*, *Crataegus monogyna*.

2. **Bed stratification.** With some plants the seeds are sown directly after collection, allowing the seed to be stratified in the bed, e.g. *Carpinus betulus*.

3. **Dry Storage.** Seeds like birch, alder and legumes are stored dry prior to sowing.

4. **Hot water.** Soaking seeds in hot water and allowing them to imbibe for 24 hours prior to sowing, i.e. *Gleditsia*.

5. **Cold Water.** Soaking seed for 24 hours prior to sowing to speed up germination, e.g. *Robinia*.

6. **Cold treatment.** Certain seeds are mixed in a peat/sand medium and placed in a cold store to remove the dormancy prior to sowing, e.g. *Pyrus communis*.

7. **Warm period.** Followed by a cold period, works with certain plants, e.g. limes, *Hamamelis*.

SOIL PREPARATION

Where possible land is left fallow and cultivated during the summer to eliminate perennial weeds or put down to mustard where possible. As much manure or spent hops that we can obtain is allocated for the seed areas.

It is applied over the area and ploughed in; this is done as early as possible during late summer to enable seed beds to be thrown up and allowed to settle naturally, also allowing early sowing to commence if required. Where land is not available until winter, it is ploughed, left and used for later sowings. After ploughing, the area may be cultivated several times before the beds are thrown up; this is governed by soil moisture at the time.

Soil sterilization. We do sterilize using bassimid, but hope on our new land to only sterilize once every 3-4 years provided weeds and diseases do not build up in the soil. Also this will reduce rotovating the soil to a minimum.

BED PREPARATION

Our beds are thrown up about 4"-6" high with a sowing area of 3"-6" and an 18" pathway on each side allowing a high clearance tractor to pass over the beds when other operations are carried out at a later date. Beds are made up with a frame containing two potato mould boards which is fixed to the three point linkage behind a tractor. It is important when making beds up to construct them with as few passes of the tractor as possible in order to obtain even compaction across the bed.

If soil conditions are good at the time when beds are being prepared very little hand work is required afterwards. As sowing may commence from late summer until mid-summer the following year, some beds may require spraying with a contact herbicide to control germinating weeds. Very light raking to loosen the surface may be necessary where the surface has capped just before sowing commences.

A dressing of phosphate is applied prior to sowing; this is raked into the surface if the operation is necessary, otherwise it is broadcast over the surface and left to be washed down. This seems to work very well with no harmful effects. In most cases where beds are thrown up early, rolling prior to sowing is not carried out; settling is allowed to occur naturally but the beds thrown up late are always rolled when soil conditions are right to provide a better soil contact with the seed. The degree of rolling is controlled by the moisture content of the soil, soil type and the time.

DETERMINATION OF THE SEED RATE

After spending a lot of time preparing the seed area, collecting, handling, and treating the seed it is important to obtain a maximum number of plants from the seed and seed bed area available. This can be achieve by sowing at the correct density. To do this we need to know the following:

a) total seed weight

b) total number of seeds

c) the viability of the seed sample at sowing

d) the required population of seedlings

e) the field factor (survival rate)

The total amount of seed is weighed and by, dividing this into a smaller unit and counting the number of seeds, the total number can be worked out. Testing a given number or weight of seed gives us the percentage or number of viable seeds capable of germinating.

Testing for viability is carried out using the following techniques:

1. **Cut test.** Large seeds, e.g. oak are cut in two, lengthways, exposing the embryo and an asessment on its condition is made.

2. **Tetrazolium.** Seeds are cut in half and placed in a 1% solution of tetrazolium for 24 hours; living tissue reacts with the chemical to produce a pink stain.

3. **Sowing.** A small sample or number of seeds are sown in trays under glass and the number or percentage of seeds that germinate are recorded.

FIELD FACTOR

This is only an assessment of the viable seeds which are capable of surviving germination and growing away to produce a plant; it is an unknown factor and can only be determined by getting to know the following:

a) *Soil* — weed seed content; diseases or pests present.

b) *Site* — Degree of exposure to wind and possible frost damage.

c) *Plant* — whether the plant is slow to develop in the early stages or grows away vigorously.

d) *Records* — only by keeping records each year of the performance, can we hope to arrive near the right figure. Using the following equation with these figures the seed rate is calculated.

$$\text{Rate} = \frac{\text{Required population of seedlings}}{\text{Sample viability} \times \text{field factor} \times \text{seed count}}$$

SOWING

When to sow? Most of our sowing is carried out in the —

a) Autumn, e.g. oaks, sweet chestnut.

b) Mid to late winter, e.g. ash, cherries, field maple.

c) Late winter to early spring, e.g. alder, birch, beech, *Gleditsia*, *Catalpa*.

030. Other sowing is carried out at different times throughout the year. Some seed arrives during the summer. Because of the season of maturation and short longevity, e.g. *Acer saccharinum*, *Acer rubrum*, and *Ulmus campestre*, seeds of these species are sown immediately on arrival.

All our sowing is carried out by hand, broadcast over the surface; if we broadcast seed at the right population the plants make better use of the space available compared with drill sowing. Heavy seeds are easily broadcasted but finer seed may be bulked up with sand to prevent the wind from moving them or

to enable the operator to sow more evenly. With large areas the seed is divided into smaller units, making the distribution more accurate. After sowing medium to large seeds it may be desirable to roll them lightly into the surface to reduce the amount of grit used. Seed is covered with ⅛" washed grit using a machine tailed behind the tractor. The depth of grit used varies according to the size of the seed, e.g. birch ⅛", beech ½".

PROTECTION

A. **Frost.** Most seeds that germinate early are prone to frost damage; those which are more severely effected, e.g. beech and limes are protected using netting.

B. **Wind.** Wind breaks using netting are erected in May to reduce wind speed, prevent scorching to the foliage and water loss from the plant and bed.

C. **Birds, Mice, Squirrels.** Can cause severe damage to certain plants if left unprotected, e.g.

Pigeons — beech, oak

Finches — pines

Squirrels — most nuts

Mice — most seeds

By cóvering beds with netting, placing drainage pipes containing a poison down the row and shooting gives us good results.

WEED CONTROL

Where germination has not taken place a pre-emergence is used wherever possible, using a contact herbicide. Once germination has taken place all weeds that emerge in the bed area are removed by hand. Pathways are sprayed with a contact herbicide using a guard to prevent drift.

NUTRITION

A top dressing using an organic NPK fertilizer is applied in spring to those beds where the seeds have germinated and later on to other seedlings as they emerge. Further applications are made during the summer, but in areas where irrigation is used the fertilizer is applied more frequently but in smaller amounts. Straight fertilizers, e.g. nitro chalk are used on plants that respond to it, i.e. ash.

IRRIGATION

Water is just as important as nutrition to maintain healthy plant growth; at present our limiting factor is the rate that we can apply the water rather than how much should we apply.

Where possible we give priority to later sowings that are prone to damage if the surface dries out e.g. finer seed, birch.

PEST AND DISEASE CONTROL

Growing plants on an intensive scale produces an unnatural environment which is suitable for the spread and development of pests and diseases. Because damage can result in loss of growth or even the saleability of the crop, regular spraying is carried out as a preventative measure rather than a cure. Spraying is done using a tractor-mounted spray with booms. Examples of pests and diseases sprayed are:

Powdery mildews — oak, field maple, *Euonymus*, sycamore (maple), thorn (hawthorn)

Aphids — birch, sycamore (maple), oaks, beech, alder

Caterpillars — *Sorbus aria*

Scab — *Pyrus*

UNDERCUTTING

At the end of the growing seasons all beds are undercut using an Egedal blade fixed behind the tractor. The depth of cutting varies from 4″ on small plants, to 9″ deep on two-year beds that were undercut the previous year.

THE PRODUCTION OF CONTAINER-GROWN TREES BY BENCH GRAFTING — SOME CRITERIA FOR SUCCESS

CLAIRE F. HOWE

Hadlow College of Agriculture and Horticulture
Hadlow, Tonbridge, Kent.

The purpose of this paper is to outline the work carried out in two group projects during our third year as students in the Ordinary National Diploma in Horticulture at Hadlow College. Besides benefitting our practical skills, our two main objectives were, firstly, to assess the suitability of the subsequent trees for garden centre sales after a one season's growing from winter bench grafting; secondly, to see how a range of genera, species and cultivars respond by being grown on under protection.

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PROPAGATION

1. *Time of Year.* The great majority of the grafting process

was carried out over a two week period commencing 5th February 1976.

2. *Rootstocks.* The rootstocks were either one-year layers or one to two-year seedlings — the latter being bare root or pot-grown. (see Table 1 for details)

3. *Scion.* The scion materials came from the two year worked trees being grown on the College's tree nursery. The choicer cultivars were kindly donated by Hilliers Nurseries of Winchester. (See Table 1 for details).

Some of the material was cold stored until ready for use.

4. *Type of Graft.* The main types of grafts used were whip, side veneer and modified side veneer grafts (see Table 1 for details). Where possible 20 to 25 grafts for each cultivar were used.

5. *Grafting Process.* The pot-grown rootstocks were "dried off" in a heated glass house prior to grafting. The rootstocks were stem and root pruned as necessary and the area where the cuts were to be made were cleaned with a dry rag. Rapidex rubber strips were used to tie in the whip, side veneer and modified side veneer grafts after which they were then waxed over, using either Arbrex, paraffin wax or "red grafting wax". The complete scion and union were dipped into the liquid paraffin wax when applied to those subjects which were whip grafted.

6. *Aftercare.* The veneer grafts were plunged into a bed containing moist peat, leaving the union just above the surface. The grafts were then covered with a semi-circular Weldmesh hoop over which we laid film plastic. Basal heat of 65° to 70°F (18.3 to 21.1°C) was maintained. In order to harden-off the grafts after callusing, one side, then both sides, of the film plastic could be lifted back for a period during the day. Eventually it could be completely removed.

The majority of the bare-root whip grafts were again plunged into moist peat contained in a rigid open container which could easily be carried by one person. No basal heat was given as these containers were placed down onto the concrete floor of the propagation glasshouse. Initially polythene film was draped over the containers but was removed to be substituted by Rokolene shading material. Where possible the air temperature was kept at around 45°F (7.2°C).

With both propagation facilities, shading was important so as to avoid scorching of the foliage when vegetative growth started from the scion buds. Regular fungicidal applications were carried out in order to reduce loss from disease such as botrytis.

Generally the results from the grafting were successful; nevertheless three problems which were experienced are worth noting.

1. Despite the Arbrex being used successfully in past years, many of the grafts where this material was applied after tying-in failed. On closer examination, it was noted that the Arbrex had penetrated into the cut surfaces and stained both the tissues of the stock and scion. The Arbrex which was used was recently purchased and was less viscous compared with the same material used in previous years.

In a subsequent conversation with Mr. R.J. Garner of East Malling Research Station it was learned the losses with Arbrex compared with the paraffin wax was almost certainly due to their different properties. The paraffin wax has a low melting point and when applied over the union cools very quickly from "inside to outside" to seal the graft. The Arbrex requires no heating and solidifies "outside to inside" thus remaining in a liquid form at the union longer than the paraffin wax would. This time period, in particular if the stock and scion are not completely matched, allows the Arbrex to penetrate the tissues of the cut surfaces.

2. The premature breaking of the rubber ties during the callusing process which caused the stock and scion to partly separate, thus bringing about graft failure by drying out of the union.

3. The premature breaking of the scion bud after grafting by high air temperatures. Where practical, the air temperature — in particular for the whip grafts — must be kept as low as possible; slow callusing process for the latter seemed very beneficial. It was apparent that this premature bud break from the scion brought about both a lower percentage "take" and poorer establishment of the grafts after containerization.

GROWING ON

Generally the containerization of the grafts was carried out some six weeks from grafting. This time period did vary mainly due to the condition of the grafts. Besides being hardened off it was very important that there should be a very minimum of scion growth prior to containerization which, in turn, could have a direct effect on the establishment of the grafts. Genera where this condition was a particular problem were *Prunus*, *Malus*, *Aesculus* and *Robinia*.

The grafts were carefully removed from the peat so as to minimize the damage to the newly-formed roots. The compost used for the containerization was an Osmocote/peat-based formulation.

The two sizes of container used were a 6¼″ (15.5 cm) and 9″ (23.0 cm) in diameter; a container of good depth is particularly important with the latter size. A proportion of the grafts were containerized with the 6″ (15.5 cm) pots to aid establishment and then subsequently re-containerized in May into the 9″ (23.0 cm) size. The remainder were containerized straight into the 9″ (23.0 cm) selling container — the advantage here being that if the grafts successfully established, costs could be saved by omitting the necessity of using the 6¼″ (15.5 cm) container.

Next the containerized grafts were placed in an unheated dutch light structure and then well watered-in. To assist the establishment it is vital that shading and ventilation be given, in addition to careful watering so as to assist in retaining even temperature and moisture gradients.

Later the ties of those grafts were removed where they had not previously disintegrated. The veneer grafts were headed back in two stages — the first at four weeks after containerizing, while the second was carried out some four weeks later. Desuckering, pest and disease control, staking, tying and trimming were carried out as necessary.

CONCLUSIONS

Through observations taken from the grafting process to the stage of growth of the subsequent trees by mid-July, the following factors seem to be important criteria for success.

1. To achieve a high percentage take from the actual grafting process attention to detail is necessary, in particular with the aftercare of the grafts.

2. At the time of containerization following the grafting process a minimum of growth from the scion is important to reduce losses after containerization.

3. As to the size of container used for the growing on, some subjects such as *Sorbus sargentiana* and *Fagus* benefited from the intermediate 6¼″ (15.5 cm) container, but the majority of plants established as well in the 9″ (23.0 cm) container. Also by July, growth was generally better where the grafts had been containerized straight into 9″ (23.0 cm) selling container.

4. Cultural practices to ensure establishment of the grafts after containerization are important as it is at this stage of the production cycle that many losses can occur.

5. The growth response of different genera, species, and cultivars vary when grown in a glass or film plastic structure.

6. Time taken to produce a saleable tree varies. It was very apparent that the cultivars of *Prunus*, *Fraxinus*, *Betula*, *Malus*, *Robinia*, *Liriodendron*, *Sorbus aucuparia* would produce a qual-

ity tree by the end of one growing season. However, *Sorbus* × *hybrida 'Gibbsii'*, *Acer pseudoplatanus 'Leopoldii'* and *Acer platanoides 'Royal Red'* would taken two season's growth, while the cultivars of *Fagus* and *Quercus*, took three years.

Finally, it is important to point out that this project was carried out by students in their final year at College and many of our results were formed by observation. It by no means lays down a dogmatic procedure, but merely points out the successes and problems we experienced. Also many points that we came across have already been discovered by experienced growers. However to us they were new and, experiencing them first hand, taught us a great deal.

For the future, more detailed investigational work is required for certain genera. Also work on costs is needed so as to ensure this production system is commercially viable.

Table 1. The scion, rootstock, and type of graft used in the project work.

SCION	ROOTSTOCK	TYPE OF GRAFT
Acer negundo 'Variegatum' *A platanoides* 'Royal Red' *A. pseudoplatanus* 'Simon-Louis Freres'	*Acer negundo* *A. platanoides* *A. pseudoplatanus*	side veneer and whip.
Aesculus × *carnea* 'Briotii'	*Aesculus hippocastanum*	whip
Betula lutea, *B. nigra* *B. pendula* 'Fastigiata' *B.p* 'Purpurea'	*Betula pendula*	side veneer and modified side veneer
Carpinus betulus 'Columnaris'	*Carpinus betulus*	side veneer
Fagus sylvatica 'Purpurea' *F.S.* 'Roseo-marginata' *F.S.* 'Tortuosa'	*Fagus sylvatica*	side veneer and modified side veneer
Fraxinus oxycarpa 'Raywood'	*Fraxinus excelsior*	whip
Laburnum × *vosii*	*Laburnum anagyroides*	whip
Liriodendron tulipifera 'Aureomarginatum' *L.t* 'Fastigiatum'	*Liriodendron tulipifera*	whip
Malus 'Profusion', *M.* 'Cowichan,' *M.* 'John Downie', *M. toringoides*	*Malus sylvestris* M.M. III	whip
Prunus × *hilliera* 'Spire' *P. serrulata* 'Kanzan' (syn. *P.s.* 'Kwanzan')	Mazzard F 12/1	whip
Pyrus salicifolia 'Pendula'	*Pyrus communis*	whip
Quercus robur 'Fastigata' *Q. frainetto*	*Quercus robur*	side veneer
Robinia pseudoacacia 'Frisia' *R.p* 'Bessonia'	*Robinia pseudoacacia*	whip

Table 1. (Continued)

Sorbus × *hybrida* 'Gibbsii' *S. sargentiana*	*Sorbus aucuparia*	whip — retaining terminal bud for *S. sargentiana*
Sorbus aria 'Lutescens' *S.a* 'Magnifica'	*Sorbus intermedia*	whip

PRODUCTION OF NORWAY MAPLE CULTIVARS BY BENCH GRAFTING

CHRIS LANE

Oakover Nursery,
Ashford, Kent.

Why propagate Norway maple by grafting and not by the accepted practice of field budding?

a) because of poor bud takes in the field, due to spring planting and sometimes the poor quality of stocks available

b) to fit in with cropping programme on the nursery (i.e. at Oakover we are seed sowing or potting container plants at critical times for the field production)

c) labour profile, i.e. (because we have peaks at planting and budding time, it is convenient to graft these in the winter)

d) to produce a well-grown maiden whip of good size for field lining (i.e. 5-7′)

e) to be able to line out in the field at 100% crop

PRODUCTION METHODS

Understocks. Strong, well-grown, 1-year seedlings are lifted from the seed-bed during the winter. These should then be carefully graded by an experienced staff member and 5-7 mm sized stocks are selected, all having good fibrous root systems. Fangy or coarse-rooted seedlings are discarded. Cut all the stocks to 12-15″ in length to facilitate ease of potting.

They are then potted up into 4″ long tom polypropylene pots during January before the main potting season commences; they are then stood down in a frame outside. They should be potted with the hypocotyl just above soil level.
The compost used is: 80% peat, and 20% sand.

To this is added — per bale of medium Irish moss peat:

12 ozs Osmocote 18N:6P:12K
10 ozs Aldrin (for control of vine weevil)

Table 1. (Continued)

Sorbus × *hybrida* 'Gibbsii' *S. sargentiana*	*Sorbus aucuparia*	whip — retaining terminal bud for *S. sargentiana*
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10 ozs Aldrin (for control of vine weevil)

10 ozs dolomite lime
5 ozs triple superphosphate
3½ ozs fritted trace elements

When the stocks begin to move in the spring, drench them with Benlate as a precaution against verticillium wilt. Any stocks showing signs of the disease should be thrown away at this time. The stocks are maintained for one growing season in the frame. They are also liquid fed at weekly intervals from April to August with Vitafeed 3:0:1. Pests and diseases other than verticillum wilt present few problems and a routine spray with Benlate and metasystox should keep stocks healthy.

The aim is to produce a healthy, well-established stock with a good root system in the pot. Drainage through the pots and the media they stand on is very important for maples in all stages of container growing; therefore, correct watering is of prime importance. If the roots are white, all is well; if they are brown you have drainage problems!

Grafting. This commences about the end of January to early February. The stocks are brought inside the glasshouse 3 to 4 weeks prior to grafting and stood on the unheated open bench. Any stocks which appear to be poorly established should be discarded as subsequent operations are costly in time and labour and any failures make it more so. They are then slowly dried off; one word of warning here though, when using no-soil composts they should not be dried right off but kept just damp. When a no-soil compost dries out you have great difficulty in re-wetting it when the graft begins to grow. By this time it may be too late as much of the root system may be dead. The stocks are cut down to 9 to 10′ to make grafting easier and also to leave a snag for excess sap to flow up which might otherwise flood the union.

The graft is made by using a side veneer graft as low down as possible on the stock. The scion should be 4 to 6″ long and of the current season's growth. The best material comes from the feathers on 2-year-old trees growing in the field. The terminal bud, however, often produces flowers, so cut the scion to a lateral bud, however, often produces flowers, so cut the scion to a lateral bud (cutting out the opposite bud at the same time), as this is more likely to be a growth bud. It is a time-consuming job picking off the flowers, but they tend to bring *Botrytis* into the grafts which can be damaging to soft growth. The graft is then tied in with a rubber strip (make a turn at the top; do not tie the flap in with subsequent turns, which should be spiralled down, leaving ⅛′ gaps between each turn and do not tie over the nick at the base of the graft and then tie-off below the nick). The graft is then stood down on the bench. The grit should be well-soaked so as to maintain a humid atmosphere. A polythene

tent is erected over the grafts to maintain humidity. Waxing of the graft is not necessary where high humidity is maintained. A bottom temperature of 65°F is given.

Aftercare. The grafts are sprayed with water and the polythene turned daily in the early stages. If it is at all sunny the grafts should be shaded with Rokolene and sprayed fairly often. Callusing occurs after two weeks and a strong union four weeks from the time of callusing. Spray with Benlate twice during this period to control *Botrytis*. The bottom heat is reduced gradually and air given morning and evening. During March, more and more air is given until the polythene can be replaced with Rokolene to harden up the growth on the scion. When the growth on the scion is 3 to 4″ long the snag is cut off and the cut waxed over. Sucker growth is removed at all stages whilst it rubs out easily with the fingers. At the time of snagging back a 2′ split cane is put in the pot and the graft and new shoot are tied in to get a good straight stem right from the start. Liquid feeding commences 2 to 3 weeks prior to potting on in April.

Potting on. The grafts are now potted on into 6″ pots by hand as this job must be done carefully.

The compost used is: 80% peat and 20% sand.

To this is added — per bale of medium Irish moss peat:
1 lb, 9 ozs Osmocote 18N:6P:12K
2 lb dolomite lime
10 ozs Aldrin
5 ozs triple superphosphate
3½ ozs fritted trace element

The pots are then stood down in a conventional 14′ polytunnel which has extended legs; this gives an extra 3′ of headroom necessary for growing container trees under protected cover. A 6′ cane is then put in the pot and the graft tied into it. Pathways must be left every so often between the pots to allow for access for tying-in operations later on; all tying in is done by machine ties. It is advisable to put some shading over the polytunnel when the grafts are moved in from the glasshouse to prevent scorching by strong sun.

Aftercare. The plants should be sprayed over regularly (especially in hot weather) after they are potted-on to aid their establishment in the new pot. They are liquid-fed each week with 'Vitafeed' 3:0:1 until the end of August. Growth is tied in to the canes as necessary.

CONCLUSIONS

The plants are field-lined in the autumn/winter to grow on as standards. Hopefully one has produced a whip, varying in size between 5 to 7′. Obviously they should be graded out when

they are field-lined. From my experience so far, whilst the maples make good growth under polythene, they do it in flushes which are erratic. It is, therefore, difficult to get a good, even crop. One important point is to make sure when potting the grafts on, that they are actively growing because then they will continue to do so. If growth has stopped it appears that the plant has to have a rest period before it recommences growth. As can be seen, this method offers a practicable alternative to field-budding for those who have the facilities. A better take (i.e. 90%) can be achieved with grafting than with field budding and whilst bench grafting and subsequent growing-on under protection may be expensive, so are the gaps caused by bud failures in the field. How often do we see a drift of *Acer platanoids* with the few *A.p.* 'Crimson King' or *A.p.* 'Drummondii' trying to fight their way up between them. With the bench grafts they can be graded and a 100% crop lined out in the field.

CONTAINER-GROWN TREES

MICHAEL CLIFT

Waterer's Nursery,

Bagshot, Surrey

There are at the outset two major subdivisions to be considered; (1) production under protected cropping — whether it be glass, polythene or woven materials and (2) in the open.

Protected cropping. Possibly the advent of the woven materials gives cause for optimism. The growing environment on a hot day for humans, at least, is more agreeable than under polythene and it is reasonable to believe the plants, too, are under less stress and also that growth would be less drawn. These materials also offer a slight amount more protection from frost damage than does polythene. Polythene with it's very quick temperature build up, particularly in the early months of the year, constantly causes anxious moments when slow-release fertilizers are incorporated in the compost. To alleviate these risks, either a reduced rate of fertilizer is added to the compost, or it is eliminated entirely, depending only on regular liquid feeding. Glass can be ventilated, as can a newer type of polythene structure, which will limit the higher temperatures of polythene, but the plants can still be at risk. I would still advocate no slow-release fertilizer but rely on regular liquid feeding to be a safer alternative.

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Irrigation under polythene structures is not a simple matter due to the inevitable underwatering and overwatering where overhead nozzles are used. Sand or matting a standing base will tend to even out the water application but allowances must be made for excess water to drain out of this base, possibly sloping the base towards the central path. As a further consideration, polythene tubing, e.g. Layflat or Seephose could also be used to apply the water at the higher point sallowing for the water to saturate the base, but again ensuring that surplus water can drain away.

Growing in the Open. Here another point must be considered — that being support for the plant. Yet another point is the matter of access for standing out and removing plants for sales. One would advocate a double-row system enabling access to two rows of plants, the simplest structure being posts and wire. Enough plant support can be provided with one wire at about 4′. When danger of frost has gone, one can transfer the plant from the protected area to the outside area. This is a logical time to also pot the plant on, potting up into a 7″ to 9″ container, depending upon the plant. Here the standard rate of slow-release fertilizer should be used. A cane should also be added to provide some support to the plant. This cane is securely attached to the supporting cross wire.

There are various ways to consider irrigating these plants.

1. A sprinkler system can be used but it is inevitable that allowing for access areas and plant spacing that a high percentage of water will miss the pots, possibly even up to 80%. I believe other methods should be considered as it cannot be certain the container is receiving sufficient water.
2. The conventional low-level trickle system, with a spaghetti supply tube to each pot, can be considered as supplying the water, with no waste, exactly where it is needed. As a modification of this method the supply pipe could be suspended above the container with a jet provided to each container position.

We have used this method for three years now. There is one storage tank, a 1½ H.P. pump which supplies the water to a 2″ main and sub-mains; the latter feeds directly into each of the trickle lines of ½″ bore and the jets spaced at every 12″ along these lines. This can be operated either manually or set on the time clock. The application rate is about 5 pints per hour and 10 minutes per day. Even in the hottest weather this has been sufficient to maintain the plants in optiumum growing conditions. One further practical consideration is that weed growth is low in both container and in the growing area.

CHIP-BUDDING POTTED STOCKS UNDER GLASS

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Abstract. Small maiden trees of Comice/Quince C, Cox/Malling 9, Victoria/St. Julien A, Crimson King/*Acer platanoides*, *Tilia* × *euchlora*/*T. platyphyllos* and *Ulmus* × *vegeta* Commelin/*U. glabra* were raised in one season under glass by chip budding newly-potted stocks in spring. The main limitation to this method of quickly producing trees suitable for sale, for example, to garden centres, appears to be poor establishment of the rootstocks, particularly noticeable in imported seedling material, which may have been partially desiccated during an extended period of dispatch.

REVIEW OF LITERATURE

Chip budding is actually a grafting method, primarily designed for use when the rind fails to part from the wood of the rootstock; it is advocated for use in the spring with cold-stored budwood (1). Recently it has been shown that a better cambial match is achieved in chip than in conventional T budding and that in England trees grow more vigorously from chip buds during their maiden season (2). This raises the possibility that by combining the potential for improved growth from chip budding with that of growing plants under glass in containers it might be possible in one season to raise maiden trees suitable for outlets such as garden centres.

MATERIALS AND METHODS

One hundred each of the following fruit rootstocks and 50 each of the ornamental species were potted into 1:7:4 loam/peat/sand compost in 7½ in. plastic pots during late February, 1974. They were grown in glasshouses initially maintained at a minimum temperature of approximately 60°F to encourage establishment. Ornamental species were transferred to a polythene structure during mid-summer after the main effects in the trial had been noted. Rootstocks used were:

Quince C pear, M.9 apple, St. Julien A (virus-free, from the East Malling nursery) and *Acer plantanoids*, *Tilia platyphyllos* and *Ulmus glabra* (imported via a commercial UK nursery).

On 24th April those rootstocks making vigorous growth were chip-budded, tying with 1.25 cm width polythene tape and avoiding the eye. Budwood, cold-stored at 0°C, of the following cultivars was used:

Doyenne du Comice pear, Cox's Orange Pippin apple, Victoria plum, and *Acer platanoides* 'Crimson King', *Tilia* × *euchlora* and *Ulmus* × *hollandica* var. *vegeta* 'Commelin'. As late

developing stocks subsequently began to grow they were also budded.

RESULTS AND DISCUSSION

In general the fruit rootstocks came into growth uniformly and vigorously, while *Acer* and *Tilia* stocks in particular were very variable (Table 1).

Table 1. Description of rootstocks at budding on 24th April

Quince C	All stocks with shoots up to approximately 10 cm length
M. 9	All stocks with shoots up to approximatley 12 cm length; three subsequently died
St. Julien A	All stocks with shoots up to 10 cm length
Acer platanoides	Stocks variably leafing-out; three were dead or dormant
Tilia platyphyllos	Extreme variation in leafing-out; nine were dead or dormant
Ulmus glabra	Most stocks growing variably; two were dead or dormant

Bud survival in the fruit plants, expressed as a percentage of rootstocks which finally grew was 100% for Comice, 84% for Cox and 64% for Victoria. Losses in the plum were associated with the presence of blossom buds in the budwood; also shields with growing shoots sometimes became loose after releasing ties. Variable bud take in field-budded plums is not uncommon.

For ornamental species bud survival was 79% for 'Crimson King', 80% for *Tilia* × *euchlora* and 75% for *Ulmus* × *hollandica* var. *vegeta* 'Commelin'.

Mean maiden growth, measured from the union (at 30 cm above pot level for Cox and 15 cm for all others) was short compared to that expected in field-grown plants produced in the normal two-year cycle, but compared very favourably with maiden whips produced in one season in the field from bench grafting. A few maidens were sufficiently vigorous to produce feathers (Table 2).

Table 2. Tree production and growth (cm).

	Maidens as % of stocks potted	Mean maiden growth	% maidens with feathers
Comice	100	70	0
Cox	81	75	0
Victoria	64	147	11
Crimson King	74	41	3
Tilia × *euchlora*	66	45	3
Ulmus ×*hollandica* var. *vegeta* 'Commelin'	72	139	56

Success, in terms of trees obtained from rootstocks potted, (Table 2) must be qualified by the considerable variability; for example, most of the 'Crimson King' trees fell equally into the four smallest size categories, whereas 'Victoria' trees fell into the majority of size categories (Table 3).

Table 3. Number of trees with maiden growth falling into particular size categories.

	Size categories (cm)										
	1-20	21-40	41-60	61-80	81-100	101-120	121-140	141-160	161-180	181-200	201-220
Comice	—	6	36	27	18	13	—	—	—	—	—
Cox	6	9	10	16	21	15	4	—	—	—	—
Victoria	—	2	4	4	7	6	4	5	5	14	13
Crimson King	9	8	9	8	3	—	—	—	—	—	—
Tilia × *euchlora*	5	9	13	6	—	—	—	—	—	—	—
Ulmus × *hollandica* var. *vegeta* 'Commelin'	—	—	—	1	6	4	5	12	2	5	1

The success of 'Comice' in particular, and also of 'Cox' and 'Commelin' elm suggests that trees which would be saleable to garden centres and which would produce branched trees in the second season can be produced in this way. In other trials, branched 'Cox' trees have been produced in one year by successfully treating the most vigorous maidens with Off-Shoot-0 tipping agent. For other species, however, factors which operate against successful establishment of the potted rootstock, or successful budding, will result in unacceptable variability due to death or poor growth in the limited time available. Contributing causes may be variability in seedling stocks enhanced by the partial desiccation sometimes experienced in imported material, and poor storage or quality of budwood. The possibility that *Acer platanoides* and *Tilia* spp. are less suitable subjects than fruit cultivars for growing under glasshouse conditions may be an additional factor, which is supported by the views of some nurserymen. *Fraxinus* spp. have produced good quality trees when raised in this manner at Hadlow College (Macdonald, personal communication).

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THE APPLICATION OF TECHNIQUES AND SYSTEMS USED IN THE RAISING OF GLASSHOUSE AND OUTDOOR VEGETABLE CROPS TO NURSERY STOCK PRODUCTION

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We can consider outdoor vegetable and protected crop plant raising under two main headings — *vegetative methods* and *propagation from seed.*

Vegetative Methods. Not many temperate vegetables are propagated vegetatively under commercial conditions — notable exceptions being rhubarb, asparagus, artichokes and, of course, potatoes. On the other hand, many of the important glasshouse ornamental plants are propagated in this way; chrysanthemums, carnations, poinsettias, alstroemerias and all the bulbs are good examples. In all instances the propagators pay great attention to the following points:

1. *Virus elimination* — using heat treatment, meristem culture and, subsequently, mother plant maintenance.
2. *Clonal performance indexing*
3. *Production of uniform propagules (cuttings/bulbs) by rapid multiplication techniques*
4. *Provision of production and crop programming advice for their customers*

Certainly points 1 to 3 also apply in the case of rhubarb and potatoes where the production of virus-free propagation material is controlled by the Nuclear Stock Association.

I feel, however, that the best examples of vegetative propagation systems and those which are most applicable to nursery stock producers are to be found in the area of glasshouse ornamentals propagation. Production of cuttings, whether rooted or unrooted, on a programmed basis is rarely done today by the producer of the finished, saleable plant. For a number of years now this aspect of crop production has largely been carried out by specialists. The techniques mentioned earlier are standard practice and closely controlled environmental conditions are used. A number of firms supply cuttings of glasshouse ornamentals and recently we have seen tissue culture techniques used by a commercial firm to propagate plants in this country. In the Netherlands tissue culture propagation of plants like an-

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thuriums and gerberas is well advanced and there are plans for a State tissue culture laboratory where commissioned work will be undertaken. In this aspect it was interesting to hear earlier Dr. Howard's contribution on the possible use of such propagation methods for fruit crops.

If such a propagation system can work in the case of glasshouse ornamentals is there not a place for programmed, pre-ordered supply of uniform cutting material from specialist propagators to the finished nursery plant producers? One has heard a number of objections to such a scheme. "The nursery sector is not big enough either in the numbers of plants of a particular type produced or in their financial value." "The transport of rooted or unrooted cuttings cannot be satisfactorily arranged." But perhaps the biggest objection usually goes unsaid. As a spectator one gets the impression that the propagation of nursery stock is surrounded by a kind of "mystique" which has been built up over the years and handed down from father to son. Are the problems of putting roots on particular subjects really that difficult that only nurserymen do it or is this just a defensive shield behind which they hide?

Is it not possible for specialist propagation nurseries to supply a particular range of material to the final producers? Of course, one does not visualize a single unit which will supply propagation material to the whole of the United Kingdom nursery industry but units which supply, for example, Erica cuttings should be possible. It may be that one of the existing propagators of glasshouse ornamentals would be interested in such a project. After all, they already have most of the facilities which would be required. Reference to date has been directed towards cuttings but one wonders if bench-grafted material could not fit into the same system.

Co-operation and confidence between the propagators and the final producers would be absolutely essential — this is one of the cornerstones on which chrysanthemums and carnation cutting production and supply is based. In the first instance it is likely that at least some of the technical propagation expertise will have to be supplied to the new propagators. The eventual "spin-off" could, however, be very great indeed. It would allow the growers to concern themselves with growing and marketing while the propagators would supply the starting material. If existing specialist propagation companies became interested in such a project then the necessary hardware would already be available in the form of propagation benches, cold-stores for holding cuttings and nurseries overseas to supply good quality cuttings in our poor light periods. Their existing computer based distribution and order processing facilities

should enable them to cope readily with new lines. Yet another benefit could arise from the routine virus-testing of material which tpese firms already carry out. They have the facilities for heat treatment and meristem propagation of their existing lines and there could be a number of interesting developments if these virus clearance techniques were applied to nursery stock.

Propagation from Seed. While vegetative propagation of vegetables and glasshouse ornamentals is almost exclusively carried out by specialists who are not the final plant producers, propagation from seed in these two sectors of our horticultural industry is nearly always done by the final producer. There are exceptions, however, and it is interesting that these are tending to increase in number. Brassica plant raisers are an accepted part of the production chain in Lincolnshire, the West Midlands and Kent; tomato and cucumber plants are raised by specialists in a number of important production areas while we have recently seen the development of a lettuce plant propagation unit on Humberside. Once again one is tempted to ask if the nursery stock producers have anything to learn from the glasshouse and outdoor vegetable producers.

There are advantages in obtaining planting material from specialist plant raisers. The specialists are able to develop the expertise and skills associated with a particular stage of a plant's life while the "grower" concentrates on others. This encouragement to develop specialist skills should lead to the production of standard, uniform plants. The plant raiser is able to invest in specialist equipment and facilities which are relevent to his particular crops. Examples include growing rooms for bedding plants and lettuce, supplementary lighting units for tomatoes, cucumbers and lettuce, and specialist precision seed drills for brassica plants. The "grower" can now devote more of his time to growing and this may allow a more intensive throughput of finished plants since labour and facilities are not involved in plant raising. One hesitates to mention the fact that it might also allow more time to be devoted to selling the final product.

No situation in this world is Utopian and here also there may be disadvantages in taking the plant raising out of the hands of the finished plant producers. There could be a reduction of staff interest. Propagation is a "plum" job on many nurseries and if it were taken away life might be more mundane. There would, naturally, be a dilution of control. Some would argue that fewer hours of sleep are lost if everything is under the direct control of the nurseryman. It is not always immediately clear, however, if blissfully peaceful nights are also equitable with maximum nursery efficiency! Yet another problem which the final producer must come to terms with is that

of being ready to accept delivery on a pre-stated date. Plant raisers also have a business to run and they need the space for the next crop which has, no doubt, also been ordered.

In many cases, vegetable farmers supply the seed to the specialist plant raisers and pay a mutually agreeable rate for plants to be ready for a particular planting date. Meanwhile the plant raisers produce an annual programme which allows them to make maximum use of their growing structures. An additional problem, of course, with nursery stock subjects is the longer period of time required to produce a transplant. It requires careful planning but, once again, I see the need for more specialist producers of nursery stock transplants from seed. In the first instance, it may be that these plant raisers work in conjunction with groups of nurserymen in particular geographical areas or who have particular production schedules.

Meanwhile we must consider the accepted techniques of vegetable plant production and then look at what is new in this field. Vegetable production has undergone a marked change during the last ten years. Today there is an increased demand for vegetables of a particular size to be grown to a predetermined programme. Supermarket claims require pre-stated quantities of particular sizes and types of vegetables which are often grown under contract. Processors have similar requirements for freezing, canning and accelerated freeze drying. The underlying factors of importance are:

(a) programming

(b) precision and, of course,

(c) quality

The least precise method of raising vegetable plants is by thick-line or thin-line sowing. Traditional seed rates are used and no assessment is taken of germination percentage. (We are fortunate that in the case of vegetable and glasshouse seeds the percentage germination and purity of a particular sample can be obtained). Thick or thin-line sowing is, therefore, a non-precision technique. Crop production from these methods of sowing can be made more precise by subsequent thinning of the crop to produce the required spacing within the rows. This is time consuming and highly labour intensive, besides which plant competition has already taken its toll of optimum growth. Very little actual broadcasting of seed now takes place in vegetable growing although thick or thin-line sowing of closely spaced crops like radish is not far removed from broadcasting.

Over the years, techniques have been developed which are far more precise right from the beginning. Spaced sowing or precision drilling ideally places one seed at every station where

a plant is ultimately required. Previous research will have determined the spacings necessary to produce crops of the required size. The problem is obvious — not all seeds germinate. When sown outside, vegetable crops such as certain brassicas, have a high percentage germination while others, such as celery, germinate very poorly. Once again the seedhouse will provide the percentage germination for a particular batch of seed and from the formula —

$$\frac{273 \times \text{number of plants required per square foot}}{\text{Number of seeds per ounce (in 1000's)} \times \text{percentage laboratory germination} \times \text{field factor}}$$

the amount of seed (in pounds) required per acre sown can be calculated. Adjustments need to be made if bed systems of growing are used but these were explained at the Cannington Conference in 1974 (P.D.A. McMillan-Browse, I.P.P.S. Annual Conference, Cannington, July 1974). Such a formula assumes, of course, that no other factors of production are limiting. Especially important in this context is the necessity for adequate weed control. There is little point using a theoretical plant spacing if weeds then interfere.

Having determined the spacing and seed rate it is now necessary to have the equipment to place the seeds as required. The earliest, and still most frequently used, precision drills depend on regular and constant seed size and shape. Thus they work best with spherical, graded seed (or seed which has been encased in pellets to produce regular spheres). Most vegetable seedhouses will supply both graded and pelleted seed on request. Pneumatic or vacuum drills have been developed recently to cope with irregular shaped seed which has not been graded. Their introduction allows at least two interesting developments. Firstly, it is now possible to precision drill irregular shaped seeds such as lettuce or carrot without the costly, and perhaps germination inhibiting, process of pelleting. Secondly, seed may now be graded according to different criteria from size. There are some indications that regular development of vegetable plants is better achieved by using seeds of similar density rather than those of similar size. Precision drills are expensive and sophisticated pieces of equipment which may be economically justified by the large scale vegetable produced but rejected by the nurseryman producing a few tens of thousands of tree seedlings. Think again of the specialists plant raiser who may be supplying seedlings or transplants to producers in his area. Is a precision drill a piece of equipment for him?

The latest development in the area of planned precision drilling has been the introduction of the concept of fluid drilling. The early work was done by the National Institute of Ag-

ricultural Engineering and the Weed Research Organization. They devised a scheme of drilling seed in an alginate gel which provided a micro-environment conducive to seed germination. The idea has recently been taken up and further developed by the National Vegetable Research Station where Drs. Bleasdale, Gray and Salter have largely been involved. Their work has been widely reported in N.V.R.S. Annual Reports, on the television programmes 'Gardeners' World' and 'Tomorrow's World' and in trade publications such as Horticulture Industry (March 1976). The original technique has now been refined to include pre-germinating or 'chitting' of the seed and also to allow ungerminated seed to be removed before drilling. For vegetables fluid drilling can best be illustrated by referring to celery seed. Field germination of celery is slow and usually very poor. Seed coat germination inhibitors are present which have a great influence unless they are regularly washed away from the vicinity of the seed. Usually there is insufficient moisture available in the soil for this to happen and the result is that celery tends to be transplanted rather than direct drilled. Facilities such as mist propagation benches in glasshouses can then be provided where the inhibitors are washed away. Pre-germination of celery seed involves 'chitting' the seed for about ten days either in a column of constantly flowing water (for large amounts of seed i.e. more than 0.5 ounces) or on constantly moistened tissue towels (small scale). Not all seeds germinate and for really precise drilling all sown units must be identical and capable of producing a plant. Ungerminated seed must not, therefore, be drilled. It is possible to separate germinated from ungerminated seed in a sloping tube down which a stream of water is gently flowing. Seeds with radicles behave like boats with sails and move quickly. The seeds with no "sail" are left behind and removed. "Chitted" celery seed can be cold stored for periods up to 14 days at temperatures of 0 to 1°C. For drilling, the seed is mixed with a suitable gel and squeezed through the nozzle of something equivalent to a toothpaste tube. A cake-icing bag may be used for small samples while special tractor-mounted equipment is necessary for field scale operations. A metering device is needed to ensure that the pre-germinated seeds are placed at regular intervals and obviously drying out of the seeds must be avoided.

What are the possible uses of fluid drilling for the nursery stock producer? Clearly "chitted" seed could be sown in outside seedbeds, always assuming that the required spacing had been determined beforehand. Little work appears to have been done on the effects of different seed spacings on the production of seedlings of different sizes for particular purposes. A more likely use for the nurseryman would be to sow "chitted" seed

into isolated growing units such as peat blocks. Machines already exist for precision sowing of non-germinated seed into containers (lettuce plant production and bedding plant sowing). It would not seem to be too difficult to adapt this equipment to put one "chitted" seed into each container.

So much for the present; now what of the future? Growers of some vegetable crops, and lettuce is again the chief example, are moving away from direct drilling and returning to transplanting even for field production during the summer months. The expense of F_1 hybrid seed has also forced some brussels sprouts producers to move back to transplanting. The problem of lettuce is, again, one of precision. The large supermarket stores require supplies regularly to satisfy a programme. Drilled lettuce develops irregularly due to a number of factors and more control of crop maturity is achieved by planting lettuce in peat blocks. The production of such plants is very much a factory-type process with seedlings of a given size being produced in blocks at pre-determined times. These are currently transplanted with adapted glasshouse lettuce planting machines but the future promises automatic, unmanned planting machines.

Much of what I have said about vegetable propagation assumes a ready, but not guaranteed, supply of seed. British vegetable producers are very fortunate. They can ring up a seedhouse, or their representative, and the required seed will arrive within a few days complete with a percentage purity and germination statement. Nursery stock producers do not have that facility. Much of the seed is imported; time of arrival is uncertain and ultimate performance cannot be ascertained from the seedsman. Home-based assessments of viability and germination are, therefore, needed before any meaningful calculation of sowing rates can be done. This situation is the status quo but surely it is only second best. Why not a British woody plant seed organization. Firms in Germany, Austria, Italy, Hungary, etc. use casual labour such as school children or family groups to collect their seed. Surely we could do something similar in Britain. Perhaps I.P.P.S. can co-ordinate collection of seed in this country. The organization in particular areas could be in the hands of Research Stations and educational institutions such as University Departments and County Colleges. Staff and students could rapidly accumulate information such as the location of good specimens of particular trees and when they are carrying good seed crops. Seed could be collected by students or even school children directed by local education authority staff. Schools are always looking for projects for their Rural Studies groups. A central I.P.P.S. group could then process the seed for distribution to members and, who knows, it may ulti-

mately be possible to get an existing home-based seedhouse interesting in doing the processing once the collecting has been done.

HOW TO TEACH ONE'S OWN SKILLS TO MEMBERS OF STAFF

KINGSLEY BUNGARD

Agricultural Training Board,
Kenilworth, Warwicks.

THE NEED. The title I shall discuss is concerned with training, an integral part of the management function in a business. If the training function is to be effective, it must be based on the needs of the company and industry. This conference has highlighted some excellent examples of needs justifying planned training and these new techniques and information have to be transferred to those who are paid to apply them.

The examples of training need include —

i) New propagation techniques

ii) New information concerning growth regulants

iii) The new entrant and casual worker who frequently enter a business with little or no related skill

iv) The member of staff already employed whose output/quality of work is not quite in line with the company's standards. For instance, budding rates and percentage take can vary quite dramatically within a gang of staff working in the same field.

As a Training Board, we have evidence that a three-day training course can very quickly improve the rate of work and the percentage take. As a trainer I see training as an economic activity — not just a social duty, and management effort in this direction should result in —

— extension of staff knowledge

— developed ability and, above all, an attitude to work that produces satisfaction to both staff and the boss.

I have tried to put the title of the talk into perspective. Clearly the teaching of practical skills to one's own staff is just one part of an overall training policy based on the needs of the company. This is a vitally important part, particularly in an industry that uses a large number of casual labour and young entrants.

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SKILL. Let's look at the word "skill" for a moment. As a trainer, and indeed any person concerned with the effective transfer of skill, we must believe that skill can be acquired — that it is not inherited but learnt. Granted, not all of us will make skillful knifesmen or budders, but given the right aptitude, training can develop a person's ability in any practical skill far quicker than learning by experience. For those who believe that the good budder has a "knack", or that propagating dwarf conifers is an art, their training will not be effective. The professional trainer believes that practical skill contains three main ingredients:

KNOWLEDGE — essential to the job

DEXTERITY — the exact movement of limbs

PERCEPTION — the way in which the senses are used

and before any teaching of skill can take place, it must be broken down into these three parts.

Allow me to cite the example of budding roses:

KNOWLEDGE	Selection of the appropriate bud — knowing how to recognize this.
DEXTERITY	Handling of the knife when removing the bud
PERCEPTION	The use of the eye when removing the bud

Anyone who is highly skilled in grafting will recognize the right-hand column as common sense and even obvious. The real difficulty lies in putting this information over to the trainee. So many of the actions, particularly in the areas of dexterity and perception are carried out subconsciously and consequently ignored when teaching other people. So often the instructor in this situation has talked to the trainee and given him all the knowledge he requries, without mentioned the precise finger movements or how he should use his senses. The trainee "has a go" and cannot do the job he has been taught, so you hear the instructor say —

"Don't worry boy — it'll come!!"

What in fact he should say,

"I'm sorry I am not exactly sure how I do the job — Sorry I can't help you".

To avoid this situation the job must be broken down and the vital teaching points clearly identified. This, in itself, is a skill and anyone selected to act as an instructor in a business requires training in analysis techniques. As a trainer of instructors I spend 50% of the course time training them to break down their own skills in order to recognize the correct teaching points. The effective instructor requires a high degree of ability and analysis techniques and this really needs noting when it

comes to selecting a member of staff as an instructor.

THE INSTRUCTOR. We now need to turn our attention to the person who instructs. What does one look for in a good instructor? He must have certain qualities, not least of all, willingness to help people to learn and acceptability to others coupled with ability to instruct. Training can do little to help develop the qualities and, therefore, evidence of these qualities should be seen in those selected to instruct. The abilities of the instructor are more important and a critical consideration in the training of an instructor. I would like to discuss five main abilities that he must either have or develop.

Able to do the job in which he instructs. I firmly believe the successful instructor must be recognized as skillful in the eyes of those he instructs. Credibility is vital and is clearly a consideration when selecting instructors. Paper qualifications are not sufficient evidence at this level of training.

Able to analyze the skills. I have dealt sufficiently with this aspect. Skills analysis can be taught and at the end of a 4-day Instructional Techniques Course, an instructor can readily identify the important points to be emphasized. This attitude towards skill is central to the effectiveness of an instructor.

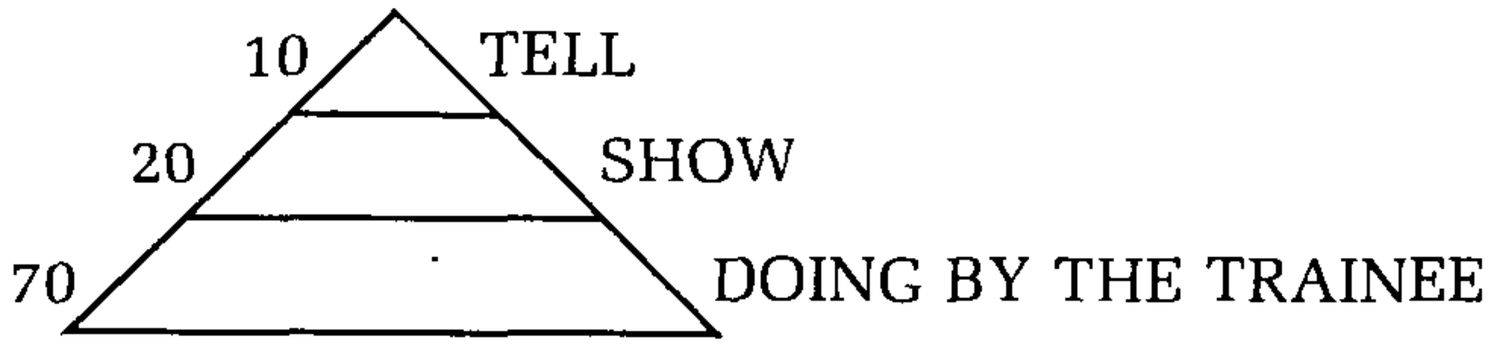
Able to apply the principles of learning. People only receive information through the senses. The ears are the weakest sense of all — sight and touch are the most powerful channels in which to feed information. Any instructional situation therefore should substitute telling for showing or demonstrating the job to be taught, leaving plenty of time for the trainee to practice. It is only when the trainee practices the skill that the dexterity and perceptual areas can be learnt. This is, of course, provided the instructor clearly recognizes the learning difficulties the trainee should be experiencing. Even more fundamental to applying the learning principles is the knowledge that people learn easier if information can be acquired in a logical sequence and can be absorbed in small quantities by the trainee. Not least of all, people can understand very easily if new knowledge and skill can be associated with something they already know or can do. Breaking a skill down into a logical sequence and thinking of "links" with the trainee's existing skill and knowledge takes preparation time; I cannot overemphasize the need to give those members of staff who instruct, time to prepare.

Able to be objective. The theorists of motivation believe that people enjoy knowing what is expected of them and whether or not they have achieved the goals set.

This principle must be applied in the instructional situation. The instructor must have a measurable objective which

states what the trainee will be able to do at the end of the training. This statement should also be communicated to the trainee, thus helping both trainee and instructor to recognize the extent of their achievement.

Able to use participative techniques. Involving the trainee and continually giving him feedback or knowledge of progress is a powerful aid to learning. The design of the training should incorporate these two aspects. A theme that we have established on our own Instruction Techniques Course in the A.T.B. is;



Within this framework, involvement and feedback can occur.

THE TRAINEE. "If learning is not enjoyable it is not worth doing" — is a phrase which the instructor should always remember. The instructor can play a large part in ensuring the degree of enjoyment, but the trainee's attitude is vital, too, and this of course is very much influenced by management. Providing the training needs have been clearly identified and the trainee senses the need for the training also, then the training objectives will be achieved. Where a training scheme at the place of work has failed, the problem has been lack of commitment and enthusiasm from the management, which is quickly reflected in staff attitudes.

This really brings me to a final point . . . if teaching skills to your own members of staff is to be effective, then a training system is required.

THE TRAINING SYSTEM. Ad hoc instruction is one approach and a lot of good training is carried out in this way. If we recognize that training is part of the management function then a declared system should be set up and all staff should be aware of its existence. The following features, in my experience, should appear.

All training to be carried out should be based on identified training needs and a written training programme prepared by both management and staff. The training programme should state the "when, where, what and how" and, of course, who instructs and who is to be trained.

Regular and planned times for training have proved to be a feature of successful training schemes — it is so easy to put off training when the pressure of work arises. Finally the selection of instructors and their training is the key to its success and, of

course, we have had the experience of training 3,500 instructors to date.

May I leave you one final thought that has been proved by experience: that if training is a part of the management function, then management should be seen to regularly guide, influence, and take an active interest in the programme of training agreed.

PROPAGATION OF JAPANESE MAPLES BY GRAFTING

D.C. HARRIS

Exbury Gardens Ltd.,
Exbury, Southampton, Hampshire

Several earlier papers presented at IPPS conferences concerning the propagation of Japanese maples have specifically described propagation by cuttings or winter grafting. At Exbury we propagate by summer grafting so a summary of our technique may help to complete the overall picture.

Understocks. Two-year seedlings of *Acer palmatum* are potted into 8 cm rigid plastic pots during the dormant season and stood pot thick in a cold frame or on a protected open bed until required for moving under glass. Towards late spring or just after new growth has started to appear the plants are cut back to 40-50 cm in order to facilitate handling at time of grafting. If this early pruning is overlooked the tops of the understocks can be cut back later in the year but it has been observed that late cutting shortly before grafting can severely reduce the foliar area at a critical time and weaken the plants. During mid- to late-June the potted understocks are transferred to a well-ventilated glasshouse and kept as dry as possible, without allowing the plants to wilt, for three to four weeks. Temperatures are maintained below 65°F, as practicable, by ventilation and shading.

Selection of scion material. Scions 10-20 cm long, preferably with three to four pairs of leaves, are selected from current season's shoots with a base of two-year wood 3-5 mm in diameter. One year wood with a firm base is also suitable, especially towards the end of the season when shoots are mature. Terminal growth should have ceased by the time scions are collected. All leaves are removed with secateurs, leaving 5-10 mm of petiole.

Grafting. Ideally grafting is undertaken between the last week in July and the end of August using a side veneer graft

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2-4 cm long tied with 6 mm wide rubber tape. It is not necessary to completely cover the union and narrow gaps between each turn of the tie are acceptable. The small flap at the base of the cut on each understock should not be tied into the scion or bruising and rotting may occur at this point. The union is not waxed. To reduce risk of disease transference from one plant to another on the graft surfaces the kinfe blade is wiped on a linen pad soaked in a solution of 4% formalin before each new understock is cut. The height of the union above soil level varies with customer requirement and cultivar, but upright-growing plants such as *Acer palmatum* 'Involuta' and *Acer palmatum* 'Senkaki' are commonly grafted at a height of 10 cms while more lax growing cultivars, such as *Acer palmatum* 'Dissectum' and *Acer palmatum* 'Linearilobum' are grafted at a height of 20-30 cm.

Aftercare. The new grafts are laid pot thick on their sides at an approximate angle of 45° in a closed case or polythene tent and shaded. Temperatures should preferably not rise above 70°F. The placing of plants at an oblique angle restricts bleeding from the cut surfaces of the understocks and subsequent separation of the graft unions. No water is given during this period. Callus starts to form after two weeks and if the petioles on the scions absciss this is an indication that the scions are alive and progressing favorably. After a further two or three weeks, when the grafts are firm, the plants are watered as required and given free ventilation. A week later the glass or protecting polythene tent is removed and the understocks are shortened back to 20 cms above the unions. Temperatures at this stage are reduced to 60°F. During November the tops of the understocks are cut back to 5 cm stubs and the new plants stood out in a protected frame until spring. The plants are snagged completely during the following March and thereafter grown on in a shaded site. Take varies from 80-95%. Best results occur on the stronger growing cultivars such as *Acer japonicum* 'Aconitifolium' and *Acer palmatum* 'Osakazuki'.

Cultivars commonly and successfully grafted include:

Acer japonicum 'Aconitifolium'
A.j. 'Aureum'
A. palmatum 'Chitoseyama'
A.p. 'Corallinum'
A.p. 'Dissectum' (and purple forms)
A.p. 'Heptalobum Elegans'
A.p. 'Heptalobum Osakazuki'
A.p. 'Involuta'
A.p. 'Ribesifolium'
A.p. 'Roseomarginatum'
A.p. 'Senkaki'

TAXUS PROPAGATION BY CUTTINGS

CHARLES SCHEER

Half Hollow Nursery Inc.
Dix Hills, N.Y. 11746

Propagation of taxus at Half Hollow Nursery has been evolving from all heated glasshouse propagation to the use of some minimum-heat plastic houses — groundbed propagation. We produce from 50 to 80,000 yews each year.

Cuttings are generally taken sometime after the third frost in the fall. We start with *Taxus cuspidata* 'Densiformis', which we sell the most of as a finished plant. Cuttings are made 8 inches long, cut on the top and bottom, with the lower half stripped of needles. After sizing, the cuttings are bundled about 50 per bundle held with a rubber band. Bundle bases are dipped in straight Chloromone which is held on a sponge in a shallow pan. We had been using Hormodin #3 powder but have found Chloromone dip faster and more effective.

Cuttings are stuck in washed coarse sand. The addition of 40 to 50% perlite has been tried on a small scale and seems to be even better. Cuttings are stuck in the heated house from November to January with an air temperature of 60° to 65°F and with a sand temperature of 70° to 75°F from hot water bottom heat. The minimum-heat house is a double layer plastic (white outside with a clear inner liner) air-supported house with groundbeds. Cuttings are taken November to February with best results from November to January.

Rooting generally takes place in the glasshouse in February and March and the rooted cuttings are planted into beds that spring. Cuttings in the minimum-heat house are rooted by midsummer and moved and healed into frames in the late summer or fall in a mixture of 30 to 40% bark tilled into the soil, plus 0-20-0 and lime. The frames are covered with a single shade until November when a second lath shade is added. Rooted cuttings from these frames are the first to be planted in beds the following spring.

Rooted cuttings are planted in 6 ft beds in four rows 1 ft apart. Cuttings are planted 8 inches apart using a lettuce pocket planter. Weeds in the beds are controlled mainly by herbicides. We have used Planavin at 2 lb ai/A plus Simazine 1 lb ai/A right after planting. With the withdrawal of Planavin we now use Surflan at 2 lb ai/A plus 1 lb Simazine in about 30 gal of water per acre as an overspray after planting. Established beds are also treated with 2 to 3 lb ai/A of granular Simazine during the winter months. Little hoeing or hand weeding is needed with these two treatments.

Beds are fertilized twice from late spring to summer using 40 to 50 lb N/A applied as a band of 50% organic N 2-1-1 fertilizer. In addition, a late fall or early spring band application of an all-chemical complete fertilizer at 40 to 50 lb N is also applied. Rooted cuttings are pruned once or twice before lifting the liners during the spring of the third growing season after planting.

PROPAGATION OF TAXUS IN NORTHERN OHIO

JAMES E. SABO

Cottage Gardens Inc.
4992 Middle Ridge Road
Perry, Ohio 44081

In looking for a simpler and more economical method of propagating taxus cuttings, we turned to ground beds in quonset type poly structures.

PROPAGATION FACILITIES

Our poly houses are 196 feet long and 16 feet wide with three beds 190 feet long, 4 feet wide, and 8 inches deep. This set-up provides us with 2280 sq ft of ground bed. Each house holds 150,000 cuttings.

Our houses are heated by 125,000 BTU Reznor natural gas hot air units controlled by a heating-ventilating thermostat. We keep a good supply of spare heater parts in our inventory. Water is supplied by outlets 50 ft from either end. With a 50 ft hose on each tap, we can cover the entire house. We also equip each house with a 220 volt electric supply and have a 15,000 watt portable generator that can supply our farm in case of a power outrage. Our water is supplied by a dual source — a well on one end and a pond on the other. If one goes out, we switch to our back-up source, or if we need a lot of water, we can use both systems simultaneously. We firmly believe it is good policy to cover all aspects in case of an emergency.

PREPARATION AND SANITATION

We fill and remove the medium from the houses by taking it out the sides, which is not only easier, but more economical. We use four different houses to alternate our crops on a 16 month basis. Therefore, we have 2 houses of cuttings and 2 houses being prepared for a new crop of cuttings at the same time.

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PREPARATION AND SANITATION

We fill and remove the medium from the houses by taking it out the sides, which is not only easier, but more economical. We use four different houses to alternate our crops on a 16 month basis. Therefore, we have 2 houses of cuttings and 2 houses being prepared for a new crop of cuttings at the same time.

After we clean the sand out, the side boards are brushed down. The next stop involves washing down with LF-10. Even though we are on 10 ft of gravel (with the best drainage you can possibly have), we put in about 1½ inches of pea gravel to insure even better drainage. Drainage is probably one of the most important factors for propagation in ground beds. On top of the gravel, we put 3 inches of a peat, sand, perlite mix. Next, we put in our sand which is a lake mason mixture (a fine sharp sand). We like this sand because it doesn't dry out rapidly. The medium is then watered down and tamped. Then the beds are treated with M-45.

When the beds are filled, we cover the house with plastic so we can fumigate it and to keep the weed seeds from blowing into the houses. We normally do this in late summer or early fall.

TAKING AND STICKING THE CUTTINGS

We generally start making our cuttings about December 1 and finish around February 1. The weather dictates when we go to the fields to take our cuttings. But, when we do go to the fields, we may take as many as 50,000 cuttings at a time. Special care is needed so the cuttings don't dry out. We try to take only the very best cuttings and hopefully of uniform wood.

The cuttings are cut to a length of 6½ inches except for 'Hicksi' which we cut at 7 inches. We strip the bottom 3 inches and treat with IBA dip. The cuttings are stuck 40 per row. We use two boards 1¾ inches wide to guide a trowel for cutting the sand. A block or stop on the trowel at 3 inches insures that the cuttings will be stuck at the same depth. After the row is stuck, the second board is placed against the cuttings and tamped with a hammer to firm in the cuttings securely. At noon and at the end of the day, the cuttings are watered heavily to insure a good firming of the medium. After a bed is stuck, we treat with Benlate. During the day, if the sun is not out to help heat the house, we turn the thermostat to 65°F otherwise, it is kept at 40° which is just enough to keep the houses from freezing. After the houses are filled, the thermostat is left at 40°F.

MAINTENANCE THROUGH THE YEAR

Watering is done by hand so that we may inspect the cuttings to detect any problems that might arise. In mid-February, we shade the house with a spray of old latex paint that we purchase for 50¢ to $1.00 a gallon. In mid-March, as the sun gets higher and brighter, we put 50% shade cloth on the houses. About mid-April to the first of May, we let the air off the houses, cut the plastic all along the side in strips to allow a free

movement of air yet keep the direct sun out. After the threat of frost is passed, we remove the shade cloth completely, remove the plastic, and replace the shade cloth. We feel it is most important to keep the cuttings under shade until winter.

Sometime in mid-October, we cover the houses with at least one layer of plastic and also replace the shade cloth. In late November, we remove the shade cloth and put on a second layer of plastic. We then inflate the houses, start the heaters, and again set the thermostat at 40°F.

ROOTING AND FERTILIZATION

Rooting occurs in July and August at which time we begin our liquid feed program. We liquid feed with Peters fertilizer every 10 days. By September the cuttings are well rooted. Now we give them a treatment of Osmocote, 14-14-14, at 50 oz/100 sq ft. This will take the cuttings into the winter in fine shape. With the layer of peat mix under the sand, the cutting roots will grow into this, and can take up additional nutrients. By January, they are rooted into the ground.

After we finish sticking our cuttings for the next year (around February 1), we go back into the houses, trim the tops with hedge shears, lift the cuttings with a digging fork so as not to tear the roots off, root prune them back to about 3 inches and heal them back in. Always remember to water. This insures good root contact with the medium. The cuttings will now develop another new root system that gives an extra heavy root system. Now we have a transplanted cuttings ready for planting out in the spring.

PROPAGATION OF TAXUS BY CUTTINGS

GERALD VERKADE

Verkade Nurseries
New London, Connecticut 06320

Two-year liners are the main-stay of our business so we root about 600,000 taxus yearly. We root in both glass and plastic-covered greenhouses. Our glasshouses use conventional hot water bottom heat but the plastic use forced hot air. In the glasshouses we use a 5″ deep medium of 1/3 perlite, 2/3 coarse sand. The medium is used 3 to 4 years by using 2% formaldehyde drench.

The plastic houses are 21′ × 96′. The cuttings are stuck in 4′ × 4′ pallets with side boards at a depth of 5″ coarse sand and plastic burlap under the medium. We have found that the air space between the ground and the medium helps maintain a 60°F rooting temperature.

November to December is the time to make all taxus cuttings to obtain rooting with the least top growth. The cuttings are taken from 2 to 20 year old plants and placed in cold storage to be made up. They are all made up in handful bunches and cut to 8″ in length with clippers. They are then stripped of needles 2½″ from the bottom and quick-dipped in 3 parts water, 1 part Chloromone.

The cuttings are then stuck, the row is opened by drawing a meat cleaver through the medium along 1″ × 2″ spacers and the cuttings placed 3/4″ apart, then firmed by tapping the spacer with a hammer and flooded in.

Rhizoctonia is the biggest problem we have after the cuttings start to root. The problem increases as the weather gets warmer. Between February and June we drench the medium 2 or 3 times with oxyquinoline sulfate at a rate 1 lb/400 gals. It is short-lived but most effective.

The cuttings at the time of planting (June 15) are 90-95% rooted; we save the unrooted ones and re-stick to plant in September.

PROPAGATION OF TAXUS CUTTINGS

JOSEPH P. VON KORNYA

Bobbink Nurseries Inc.
Freehold, New Jersey

We start our cuttings in the fall after 2 to 4 killing frosts. The spreading types we make 6″ long, the uprights 8″, using the current year's growth. The cuttings, depending on cultivar, are treated with Hormo Root B (15% thiram, 0.40% IBA). For hard-to-root kinds we use Hormo Root C (15% thiram, 0.80% IBA). Easy cultivars are *Taxus cuspidata* 'Densiformis', *T. cuspidata* 'Compacta', and *T.* 'Green Mountain'. The harder ones are *Taxus* × *media* 'Wardii', *T.* × *media* 'Hicksii', *T.* × *media* 'Hatfieldii', *T. brevifolia* 'Nana', our patented *T.* 'L.C. Bobbink', a globe-shaped taxus, and the only real troublemaker, is *T. baccata* 'Repandens'.

All cuttings are stuck in pure perlite about 1½″ to 2″ deep. Spacing is 1/2″ × 2″. The medium is kept at 65° to 68°F. I believe bottom heat is very important. The cuttings are lightly syringed 2 to 3 times a day to maintain high humidity in the greenhouses. They are dusted with Captan every 2 weeks, especially for damping-off. We have found that it is best to finish all our taxus cuttings before January 1; cuttings taken later develop a heavy top growth and callus, poor rooting, and are often attacked by damping-off organisms.

When roots first develop watering is gradually cut down; and the costly heat is cut by about 10°F. Most cuttings are planted in June, into beds 5 feet wide, spaced 6 × 10 inches. The harder to root cultivars are potted in 3″ Jiffy Pots and kept in cold frames. We undercut the stock in our field beds the second and third year to establish a compact root system. The feeding is very light and the trimming is done with a 5 foot rotary mower.

In the fourth year we line out a heavy 8-10″ liner and are able to finish a 15-24″ plant of most cultivars in 2 years. The plants are spaced 2 × 3½ feet. The pH is kept around 6.5. Feeding is done by mechanical side dressing with a 10-6-4, 50% organic fertilizer. Trimming is done once in the winter and once in the summer. We use Freunde hedge shears. Weed control is done in late February with 50 lbs/A granular Simazine applied with a Lilly spreader. We cultivate at least every 2 weeks mechanically; hard to control weeds are hoed out.

JAMES WELLS: I have a couple of questions for Jim Sabo. Do I understand correctly that you're rooting these taxus stuck in ground beds at a consistent 40°F air temperature?

JIM SABO: We set our thermostat at 40° and use no bottom heat. Of course, during the day when the sun is out the temperature will go above this.

JOHN MCGUIRE: What is the canning mix in which you grow these taxus?

JIM SABO: A few years ago we ran a growing mix study and at the end of 2 years we couldn't see any difference in the six mixes we were testing and so we went back to our standard container mix which is 50% bark and 50% peat moss; to this we add superphosphate and other nutrients.

JOHN MCGUIRE: How much water do they get?

JIM SABO: A lot. I feel the key to growing taxus is nutrients and keeping the roots cool and it takes a lot of water to keep the roots cool.

JACK GARTNER: Do you grow your taxus under shade?

JIM SABO: Yes, we use 50% Saran. In comparing plants grown in full sun and those grown under shade, those under shade are always much darker green.

CARL ORNDORFF: Why don't any of you use straight perlite as a rooting mix, then you wouldn't have to use all of the fungicides you are putting on?

GERRY VERKADE: I tried using straight perlite but the roots went out rather than down and it made them difficult to transplant; by using 1/3 perlite, 2/3 sand, I get the roots to go down.

CARL ORNDORFF: I use straight perlite all the time and have never had a problem with the roots.

FROM QUEST TO SYSTEM IN MEDIUM RESEARCH

BETSY SCARBOROUGH

The Conard-Pyle Co.
West Grove, Pennsylvania 19390

The nursery market is becoming increasingly competitive and the emphasis in production is to produce better quality plants. To improve quality the optimum growth conditions for each crop must be investigated. By manipulating microenvironments, those alterations resulting in positive growth responses can be selected and incorporated into the production system.

In our quest for improved quality one factor, medium, has received intensive study. Our standard production medium was a peat:sand mix, 3:2 (v/v) for ericaceous plants and 1:1 (v/v) for hollies, roses, junipers, euonymus, cotoneaster, and metasequoia. Our initial tests centered around the introduction of hardwood bark into the medium.

Through our experiments with hardwood bark as a medium component we hoped to answer several questions.

1. Were hardwood bark mixes superior to peat:sand?
2. What effect did particle size of the bark have on plant growth?
3. Was peat a necessary component in our hardwood bark mix?
4. Should bark be composted with urea or ammonium nitrate?
5. Did hardwood bark mixes contain more air space than peat:sand mixes?

The following five media were selected for study: 1) peat:sand (3:2 or 1:1); 2) coarse bark:peat:sand (2:1:1); 3) fine bark:sand (3:1); 4) coarse bark:sand (3:1) and 5) coarse bark:peat:sand (2:1:1) composted with urea.

Prior to mixing, each cubic yard of bark was composted with 9 lbs of ammonium nitrate with the exception of medium 5 which received 4.5 lbs of urea. In addition to the nitrogen source, 4 lbs of treble super-phosphate, 2 lbs of G.U.-49 (63% iron oxide) and 2 lbs of Aqua Gro were added per cubic yard of bark. After composting 6 weeks, the bark was mixed with the remaining medium admendments.

The coarse bark was hammermilled through a one-inch screen resulting in 31% of the particles greater than 1/4 inch and 12.7% less than 1/50 of an inch. The fine bark contained only 2.7% of the bark greater than 1/4 inch and 31.8% less than

1/50 of an inch.

The test plants, representing 5% of each cultivar grown at The Conard-Pyle Co. were transplanted into 2 or 3 gal containers on June 16, 1975. These plants received routine care, that is, weekly pesticide sprays and constant feeding at 150 ppm N of 15-20-24 fertilizer during the growing season. Final evaluation was taken August 12, 1976.

All 2-year container-grown plants in the coarse bark:peat:sand medium had better root and shoot growth than those grown in peat:sand or fine bark:sand (Tables 1 and 2). Lateral branching was also more developed on plants grown in the bark mixes versus the peat:sand. Only with the 1-year crops of euonymus, cotoneaster and metasequoia was growth in the peat:sand better or equal to the bark mixes.

Under our conditions the coarse bark produced better quality plants than the fine bark (Table 2). From additional tests using supplemental feeding with Osmocote 18-6-12, we were able to demonstrate that part of the reduced growth from the fine bark was due to nitrogen deficiency. Possibly more than 9 lbs of NH_4NO_3 was necessary in composting the fine bark because of the increased surface area.

The addition of peat to the bark:sand medium resulted in better growth (Table 2). One advantage of the peat as a component in the bark mix appeared to be an increase in water-holding capacity of the medium. Thus less frequent waterings were necessary.

Table 1. Size grade of *Ilex* 'Blue Angel', grown in experimental media.

	Percent		
Medium	Culls	10″-12″	12″-15″
Peat:Sand	97	3	0
Coarse-Bark:Peat:Sand	38	62	0
Fine-Bark:Sand	83	17	0
Coarse-Bark:Peat:Sand	26	72	2

Table 2. Size grade of *Rhododendron* 'Nova Zembla' grown in experimental media.

	Percent			
Medium	Culls	12″-15″	15″-18″	18″-21″
Peat:Sand	47	37	16	0
Coarse-Bark:Peat:Sand	9	27	41	23
Fine-Bark:Sand	35	65	0	0
Coarse-Bark:Sand	25	32	34	9
Coarse-Bark:Peat:Sand (urea as N source)	10	13	37	40

Depending upon the cultivar being grown, urea could be substituted for ammonium nitrate as the nitrogen source during

composting. For the rhododendrons, 'Blue Angel' hollies, and junipers tested, better or equal growth was obtained in urea versus ammonium nitrate-treated bark. For pieris and Exbury azaleas ammonium nitrate was the superior nitrogen source (Table 3).

Table 3. Size grade of *Juniperus horizontalis* 'Wiltoni', *Pieris japonica* 'Compacta', *Ilex* 'Blue Angel' and *Thododendron* 'Roseum Pink'(?) grown in bark:peat:sand composted with urea or ammonium nitrate.

Variety	Nitrogen Source	Percent					
		Culls	*10-12"*	*12-15"*	*15-18"*	*18-21"*	*21-24"*
J. horizontalis 'Wiltoni'	NH_4NO_3	8	32	32	28		
	Urea	11	33	42	14		
P. japonica 'Compacta'	NH_4NO_3	3	41	53			
	Urea	17	55	28			
I. 'Blue Angel'	NH_4NO_3	38	62	0			
	Urea	26	72	2			
R. 'Roseum Pink'(?)	NH_4NO_3	0	0	13	35	39	13
	Urea	0	0	10	22	52	16

The available air space in freshly-prepared peat:sand (3:2) was only 12.7% whereas the air space in freshly prepared coarse-bark:peat:sand was 36%. After 15 months, the air space was reduced to 9.5% in the peat:sand medium while the air space in the bark medium was 19%. Even freshly prepared, the peat:sand medium contained less air space than the amount considered adequate for good plant growth, which is 15-25% (1).

Through observations, several other advantages of the bark:peat:sand medium were noted. The bark mixes, due to composting, had fewer weeds initially than the peat:sand medium. This meant 1 to 2 fewer hand weedings the first summer and less competition to impede plant growth. Secondly the bark mixes appeared to suppress certain plant pathogens that were active in the peat:sand medium. Reports indicate that composting pasteurizes the medium and antagonistic microorganisms and chemicals in composted bark contribute to control of plant pathogens (2). Nutrient and water retention of the bark mixes increased with aging and were higher than the peat:sand. Although the water retention was better in the bark, the drainage in the bark was also superior to the peat:sand medium thus lowering the susceptibility to infestation by root rot fungi. Finally the difference in weight per 3 gal container, peat:sand weighing 32 pounds at field capacity and bark:peat:sand weighing 22.5 pounds, resulted in increased productivity in handling the containers.

In summary, not only was the quality of the plants grown in bark:peat:sand improved but also the production efficiency in growing these plants increased. The plants grown in coarse-

bark:peat:sand had larger root systems, were generally one size grade larger and were fuller plants due to increased lateral branching. The peat not only improved the growth when mixed with the coarse bark but reduced labor costs by reducing the number of waterings needed. The coarse bark, which is more *readily available to us, produced better plants than the finely* hammermilled bark. Although further testing is warranted, either urea or ammonium nitrate could be used as the nitrogen source which allows us to be flexible with the fertilizer market.

As for production advantages, less frequent waterings were necessary with the bark mixes, fewer weedings were needed the first summer and fewer pesticide drenches were required. Finally, worker productivity was increased during canning, spacing and shipping due to decreased weight of the media. These results have been incorporated into our production system and we are now completing our first growing season with plants in a bark:peat:sand medium.

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1. Buscher, F.K. and D. Van Doren, 1972. Determination of air-filled pore space for container-grown nursery stock. *Area Nursery and Garden Store Newsletter.* No. 149.
2. Hoitink, H.A.J. 1976. Composted bark media for control of soil-borne plant pathogens. *Presentation at 101st AAN Convention.*

HOW TO GROW MINIATURE ROSES

EZEQUIEL COLLAZO

The Conard-Pyle Co.
West Grove, Pennsylvania 19390

The story of present day miniature roses in the United States has been created mostly by two men: the late John de Vink of Boskoop, Holland, and the late Robert Pyle of The Conard-Pyle Co., West Grove, Pennsylvania. When Mr. Pyle was in Europe in 1933 he visited Mr. de Vink in Holland and found him experimenting with the breeding of miniature roses for his own amusement. Mr. Pyle was charmed with the idea of having "Fairy Roses", as he thought of them, and was sure they would be popular if he could produce them on a commercial scale. This would also permit Mr. de Vink to afford to keep amusing himself by developing more, and better, cultivars.

The miniature rose is a newcomer to the West. Miniature roses were known in England early in the 19th century. It is believed that the plants were a form of *Rosa chinensis* 'Minima'

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found by traders in the Far East, and brought in from China or Japan, where they had been dwarfed by patient oriental art. This little rose, known as *Rosa pusilla* (*Rosa humilis*) when it first came to England, was there renamed in favor of Mary Lawrence, a popular exhibitor at the Royal Academy, whose specialty was flower paintings. "The first drawing of this charming little rose", says Miss Willmott in her Genus Rosa Vol. I, "appears in the Botanical Magazine of 1815, where it is called '*Rosa semperflorens*'." Two cultivars appeared and were called *Rosa lawrenceana* varieties, one credited to Roudoute in 1821, and the other, *Rosa Lawrenceana* 'Alba', to Mouget in 1827.

Later, these little roses were apparently lost to cultivation. A century later a miniature rose was again found — this time in Switzerland — and propagated by Henry Correvon, a Swiss nurseryman, and named *Rosa roulettii* by him for the man who rediscovered it.

Mr. John de Vink had plants of this *Rosa rouletti*, and he was crossing them with any pollen that he had on hand. His first miniature rose was sent to The Conard-Pyle Co. in 1934 and was patented and introduced in 1936. It was named *Rosa* × 'Tom Thumb', and was the first patented miniature rose. There are now a large number of different cultivars in various colors on the market.

The size of miniature roses ranges from 8 to 15 inches high; the bloom sizes range from 1/2 to 1½ inches, and the petals range in number from 10 to 80. Some have single blooms, while others bloom in heavy clusters; all are constant bloomers.

Miniature roses can be grown indoors or outdoors. Indoors they do well in a sunny window or balcony. Outdoors they can be grown in any part of the garden in full sun; 6 hours of sun is sufficient to grow them well. Pests are not a problem but plants should be sprayed at least every 2 weeks to prevent disease. A light dose of fertilizer in early spring and again in early summer will give them plenty of nutrients.

We grow approximately 250,000 miniature roses yearly. We start mother plants in the field, using *Rosa multiflora* understock. We bud them in summer, in late winter the tops are cut leaving just the bud. The following summer we take cuttings from these plants. We go to the stock block in the morning and take cuttings for 2 hours, enough cuttings for a day's work. The cuttings are 2-3 inches in length and cut right under the bottom node for better rooting. They are dipped in 0.1% IBA powder, stuck directly in 3 inch plastic pots filled with 50% peat/50% perlite, and placed on benches in a glass greenhouse or in plastic-covered quonset huts.

We mist 30 sec each 5 min from 8:30 a.m. to 5:30 p.m. About 10 days after the cuttings are stuck, we begin to cut down the mist. Miniatures take 2-3 weeks to root, and as soon as they are rooted we start to feed them using 150 ppm N of Peter's 20-20-20 on a constant feeding program. We spray every 10 days with Phaltan, Diazinon and Manzate.

A few weeks later these plants are moved outdoors to quonset huts, and are heeled in sand about 2-3 inches deep to prevent root damage during cold weather. We continue with the same feeding and spraying program we used indoors. In late fall we cover the quonset huts with a single layer of 6 mil poly film for winter protection. At this time these plants are ready for sale.

Our sales are approximately 85% wholesale and 15% retail. For shipping, the plants are cut back to about 4 inches and wrapped in aluminum foil to prevent the soil mix from coming out of the pot. They are ready for forcing when the customer receives them; forcing takes about 6 to 9 weeks, depending upon the cultivar.

INJURY TO SELECTED PLANTS DUE TO FLUORIDE TOXICITY

R.W. HENLEY, R.T. POOLE and C.A. CONOVER

Agricultural Research Center, Apopka
Apopka, Florida 32703

Chlorosis and necrosis of plant foliage is caused by various agents including: disease causing organisms, insects, mites, nematodes, high soil salinity and air pollutants. Occasionally, foliar problems cannot be directly attributed to these causes. Such is the case with certain plants which respond to excessive fluoride ions in irrigation water, soil solution or fertilizer. As recently as 1971 (5), the necrotic lesions which often develop on the distal portion of leaves of Cordyline terminalis propagated from terminal cuttings was reported to be of a non-pathogenic nature. Research findings at that point indicated that *Cordyline* could be propagated best if cuttings were stuck in either calcined clay (Turface) or Louisiana sedge peat, in preference to other available rooting media.

The first report of fluoride toxicity in tropical foliage plants was made by Conover and Poole (1) in late 1971. Freshly harvested cuttings of *Cordyline terminalis* 'Baby Doll' developed

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The first report of fluoride toxicity in tropical foliage plants was made by Conover and Poole (1) in late 1971. Freshly harvested cuttings of *Cordyline terminalis* 'Baby Doll' developed

necrotic lesions primarily on the margin near the distal portion fo the lower leaves when the bases were immersed in tap water which contained 0.25 ppm fluoride.

Table 1. Effect of water source on foliar necrosis and fluoride content of *Cordyline terminalis* 'Baby Doll'.

Treatment	Necrosis rating[1]	Foliar F (ppm)
Distilled H_20	1	0.2
Tap H_20 (0.25 ppm F)	2	2.8

[1] 1 = no necrosis, 5 = 100% necrosis.

Further investigations (1) revealed a positive correlation between the amount of fluoride supplied to unrooted *Cordyline* cuttings, the fluoride content of the foliage and amount of necrosis observed (Table 2).

Table 2. Necrosis and leaf fluoride of *Cordyline terminalis* 'Baby Doll' propagated in tubes containing fluoride solutions.

Fluoride Solution (ppm)	Necrosis Rating[1]	Leaf F (ppm)
0.00	1.4	2.8
0.15	3.2	6.2
0.30	4.0	11.7
0.45	4.9	13.5
0.60	5.9	16.5
0.75	6.0	17.2

[1] 1 = no necrosis, 10 = complete necrosis (dead).

The same researchers noted the importance of selecting soil amendments and fertilizer additives carefully for *Cordyline terminalis* (2). Table 3 lists the soluble fluoride content of several soil amendments. The leachate from both German peat and perlite contained relatively high levels of fluoride.

Table 3. Fluoride content of various media used for propagation and growing foliage plants.

Medium	Soluble fluoride on a dry weight basis (ppm)
Cypress shavings	0.5
Zellwood peat	1.5
Calcined clay (Turface)	2.5
Louisiana sedge peat	3.0
Pine bark	4.5
German peat	19.5
Perlite	86.0

In addition to the influence of propagation or growing medium on fluoride supply, the effect of superphosphate applications to selected media was reported (6). Normal superphosphate and concentrated superphosphate contain mean levels of 1.64 and 1.56% fluoride, respectively (3). Superphosphate at the

rate of 5 pounds per cubic yard increased foliar fluoride levels and leaf necrosis. Additions of liming materials decreased leaf fluoride and necrosis caused by German peat and superphosphate (Table 4).

Table 4. Effects of soil amendments on pH of German peat and necrosis and foliar F of *Cordyline terminalis* 'Baby Doll'.

Superphosphate	Liming Material (lb/yd³)	pH	Necrosis rating[1]	Tissue F (ppm)
0	0	4.1	3.8	27
0	$Ca(OH)_2$	2.5	5.4	4.2	26
0	$Ca(OH)_2$	5.0	5.8	4.4	23
0	Dolomite	5.0	5.2	4.5	26
0	Dolomite	10.0	5.6	4.7	27
5	0		10.0	137
5	$Ca(OH)_2$	2.5	4.6	6.6	40
5	$Ca(OH)_2$	5.0	5.4	4.5	31
5	Dolomite	5.0	4.4	8.1	53
5	Dolomite	10.0	4.8	7.5	43

[1] 1 = no necrosis, 10 = complete necrosis (dead).

An experiment was designed to determine the influence of time after harvesting *Cordyline* cuttings prior to exposure to fluoride solutions on the quality of the rooted cuttings. Harvested cuttings were held for periods up to 7 days with bases *immersed in deionized* water prior to transferring them to a 1 ppm fluoride solution. Table 5 indicates that approximately 4 days after harvest, terminal cuttings develop a selective mechanism which reduces the rate of fluoride uptake. This transition is associated with wound healing and root development.

Table 5. Leaf fluoride and grade of *Cordyline terminalis* terminal cuttings as influenced by time prior to exposure to a one ppm fluoride solution[1].

	Days in Deionized Water					
Measurement	0	1	2	4	7	10
Leaf F (ppm)	11.3	8.7	7.7	6.7	4.7	4.0
Grade[2]	5.0	5.0	4.0	2.0	2.0	1.0

[1] Samples collected on 10th day.
[2] 1 = no necrosis, 10 = complete necrosis (dead).

Since perlite is an important amendment for propagation media, it was felt that possibly the fluoride could be reduced by leaching prior to use for propagation. An experiment was designed to recover leachate from new perlite samples obtained from two sources. Each perlite sample was sequentially leached 5 times with deionized water in a ratio of 1 part perlite to 10 parts water by volume. After the leachate was recovered, tip cuttings of *Cordyline* were placed in the solutions for a period of 2 weeks and then evaluated (Table 6).

Table 6. Influence of sequential leaching of perlite on fluoride toxicity of *Cordyline terminalis* rooted in perlite leachate.

Treatment and Perlite Source	Necrosis rating[1] Leachate number 0	1	2	3	4
Deionized Water	1.0	—	—	—	—
Perlite (Source A)	—	4.7	2.5	1.5	1.0
Perlite (Source B)	—	4.5	1.7	1.3	1.0

[1] 1 = no necrosis, 5 = severe necrosis.

Data on the rooted cuttings suggest that after new perlite has been thoroughly leached, it is safe for use as an amendment in propagation media and soil mixes for fluoride-sensitive plants.

Following the work on *Cordyline*, researchers at the Agriculutral Research Center, Apopka began investigating a different pattern of chlorosis and necrosis which appears frequently on leaves of *Dracaena deremensis* 'Warneckii' (7). Necrotic spots develop in the white portions of the foliage near the tip with occasional lesions along the margin. The time required for development of necrotic spots on *D. deremensis* 'Warneckii' terminal cuttings was approximately 8 weeks when soluble fluoride was available in the propagation medium. The use of intermittent mist reduced the intensity of leaf necrosis although it did not reduce the leaf fluoride level in most treatments. The exact mechanism of retarding the development of fluoride toxicity through the use of intermittent mist is not well understood but it is believed to change the pattern of fluoride accumulation in the foliage which occurs when cuttings transpire rapidly.

In another report, the influence of light intensity on the development of necrotic spots on the foliage of *D. deremensis* 'Warneckii' was shown (2). Plants grown under 60 and 80% shade had less than half the number of blemished leaves as those grown under 40% shade.

Other studies have shown that marginal necrosis often found on *Dracaena deremensis* 'Janet Craig' (8) and *Chlorophytum comosum* (9) can be induced by additions of normal superphosphate. Recommendations listed below are directly applicable to plants in the genera: *Chlorophytum*, *Cordyline* and *Dracaena*. Other species and cultivars in the families: *Agavaceae*, *Liliaceae* and *Marantaceae* are suspected to be sensitive to fluoride (4).

Recommendations for minimizing fluoride phytotoxicity when propagating and growing fluoride-sensitive plants are as follows:

1. Avoid use of superphosphate as a fertilizer. Phosphorus should be supplied from other sources.
2. Use water which contains less than 0.25 ppm fluoride. Remember that municipal water treatment often includes the addition of 1.0 ppm fluoride to reduce the incidence of tooth decay.
3. Use soil components which contain low levels of fluoride. Of those materials tested, perlite contained the most fluoride followed by German peat. It is suggested that perlite be preleached before incorporation with other amendments.
4. Adjust the soil pH between 6.0 and 6.5. Within this range fluorides are not as freely available to the plant as when the pH is lower. Additions of 3 to 10 pounds per cubic yard of limestone or dolomitic limestone at the time of soil preparation is usually sufficient. Additions of up to 1 pound of hydrated lime per cubic yard can be used on plants which have been potted.
5. Avoid environments which accelerate the rate of transpiration and subsequent uptake of fluoride. These adverse factors include high light intensities, excessive air movement and high temperatures.

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Monday Afternoon, August 23, 1976

The afternoon session convened at 1:30 p.m. with Mr. Andy Knauer serving as moderator.

LEAF ANALYSIS — A GROWTH INDICATOR

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Abstract. Leaf analysis, a well established diagnostic tool, should be used by the nursery industry, along with soil analysis, to diagnose suspected nutritional disorders, detect deficiencies prior to visual manifestation and, most important, to monitor the mineral status of plants during the growing season. Sufficient values are listed for 12 elements as a guideline for fertilizer determinations.

What is Leaf Analysis? The terms "plant," "tissue," "foliar" and "leaf" analysis have all been used synonymously to describe the procedure used to determine the nutritional condition of the entire plant. The term "leaf analysis" will be used in this discussion since the leaf or foliage is the most frequently used tissue. Leaf analysis utilizes the relationship that has been found to exist between the nutrient content of a leaf and the growth and yield of that plant.

Leaf Analysis Background. Leaf analysis has been used for years as a method of diagnosing plant nutrient disorders and making fertilizer recommendations for many agronomic and horticultural crops. The mid to late 1930's was the beginning of a popular trend to develop leaf analysis as a useful research and production technique. The first grower service laboratories were established by Kenworthy at Michigan State University in 1949. Benjamin Wolf in Florida in 1949 and by O.A. Matkin in California in 1950 (2). Private or University laboratories have now been established in most states for leaf analysis in both horticultural and agronomic crops.

In landscape or ornamental horticulture the utilization of leaf analysis by the industry has been much slower because research has been limited to only a few species. Early work in ornamentals centered on the genus *Taxus* by Boonstra, Kenworthy and Watson (1) in 1957 and Kelly and Shier (5,6) in 1965. Work with a wider group of trees and shrubs was conducted by Cannon, Chadwick and Reisch (3) in 1960, Davidson (4) in 1960, Smith (8) in 1972 and Lumis (7) in 1975.

Advantages of Leaf Analysis. Much of the current information on ornamentals nutrition, as well as other crops, can be attributed to the adaptation of leaf analysis. Prior to the general

use of leaf analysis, many fertility experiments were conducted to determine the effects of a given type or rate of fertilizer on a crop, but without leaf analysis much of their value was lost for anything but localized recommendations or comparisons. Through leaf analysis, however, this mineral leaf value-growth relationship has been found to be sufficiently reliable from year to year and from one soil type or cultural condition to another that standards have been developed for various crops. Thus, leaf analysis represents a more universal means of determining plant nutrient condition.

Another advantage of leaf analysis is that it is a more accurate procedure to determine plant nutrition status than visual evaluations, rapid tissue tests and soil tests. Leaf analysis, however, should be used in conjunction with soil testing in order to continue to obtain soil pH, soluble salts, base exchange capacity, percent base saturation and organic matter level.

How is Leaf Analysis Used in the Nursery Industry? Leaf analysis is used by the landscape and grounds maintenance sectors primarily for diagnosing nutritional disorders. Most samples arriving in The Ohio State University laboratories have dealth with chlorosis problems of maples, oaks, pines and an assortment of shrubs.

Although producers are using this procedure for diagnostic reasons, more growers each year are utilizing leaf analysis as a method of monitoring their nutritional program. Container plant producers on liquid fertilizer programs utilize leaf analysis most frequently, as expected. A monitoring program every 2 to 4 weeks allows producers to adjust their fertilizer injections according to plant mineral element levels and, thereby, program growth accordingly. Another advantage of a monitoring system is the opportunity to detect suspected nutrient deficiencies before unsatisfactory growth occurs.

The greatest return from fertilizer dollars is to achieve optimum plant growth with minimum investment. The utilization of leaf analysis, the most modernistic technique available, will assist in determining the proper amount of fertilizer to apply. The cost conscious nurseryman utilizes a leaf analysis service as a plant growth indicator.

Sampling Guidelines. The optimum time of year to sample plants, since mineral element levels vary during the season, is between late June and late September in Ohio. Samples should be taken by removing the most recently matured leaves from 15 to 20 or more healthy plants or from as many different plants as possible showing a suspected disorder. Depending on leaf size, between 30 and 50 leaves should be removed from deciduous plants and broadleaf evergreens. All tissue samples should be

taken from the current season's growth and should be free of insect and disease infestations as well as other disorders.

The leaf analysis program, in those states offering such a service through a Land Grant University, is usually administered through the County Cooperative Extension Service. A number of private laboratories also offer leaf analysis services. A routine leaf analysis will usually cost between $7.00 and $30.00 depending on the laboratory.

Acceptable Values. Through survey research, fertilizer rate studies and analysis of grower reports during the past several years at Ohio State University, leaf analysis guidelines have been developed for woody ornamentals (9). Sufficient ranges are outlines below based on determination of nitrogen by the automated Kjeldahl process and of all other elements by direct reading emission spectrograph.

Nitrogen — A range of 2.0 to 4.5% is recommended with levels closer to 2% by late summer.

Phosphorus — A range of 0.2 to 0.6% is usually sufficient for healthy foliage and satisfactory flowering.

Potassium — Levels between 1.5 and 3.5% should be maintained, although evergreens often exhibit levels closer to 1.0%.

Calcium — A range of 0.5 to 2.5% is usually found; however, early in the season and in soft growth of terminal cuttings levels are lower.

Magnesium — The desired range is between 0.3 and 1.0% with the exceptions noted with calcium above.

Manganese — Levels vary between 30 and 800 ppm.

Iron — A range of 50 to 700 ppm is considered sufficient although variations exist and deficiencies may occur above 50 ppm.

Boron — Levels between 20 and 50 ppm are satisfactory.

Copper — Growth of plants is satisfactory when copper levels are between 10 and 50 ppm.

Zinc — Thirty to 75 ppm are considered necessary for optimum growth.

Molybdenum — a range of 0.6 to 6.0 ppm is sufficient.

Aluminum — Levels above 800 ppm are likely to be toxic.

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COMPOSTING SEWAGE SLUDGE IN THE NURSERY

HAROLD E. STONER
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Westminster, Maryland 21157

In 1974, Dr. Francis Gouin introduced to this Society, the possibilities of using composted sludge in container growing mixes. His talk aroused my interest enough, that upon returning home, we immediately procured 40 tons of digested sludge from one of the Baltimore waste-water treatment plants. We composted this material using 2 parts aged hardwood bark and 1 part digested sludge. After composting thru the months of January, February, and March, using a front-end loader to turn the pile, a test was taken. The results were: pH 5.6, magnesium 300+ (V.H.), phosphate 510 (V.H.), potash 258 (H), soluble salts 3200 ppm (hot).

We consulted with Dr. Gouin, and a decision was made to add soil to reduce the soluble salts to a safe level. We used a half compost and half top soil mix for planting 500 shade and flowering trees in baskets. When the planting was completed, they were heeled-in with a hardwood bark mulch and top-dressed with nitrogen. There was not much different at first from our previous method of using a highly organic top soil, but as soon as mid-summer came and we got less and less rain,

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the difference started to show. The containers with the compost mix retained moisture longer and the plants retained a darker and healthier color.

In the meantime, we had inquired about contracting for 1500 tons per year of digested sludge from Columbia City Treatment Plant at Salvage, Maryland. The superintendent of the plant welcomed the idea and started the necessary inquiries to his Howard County supervisors. Two days later, we were informed that a permit from the Maryland Dept. of Environmental Health would be needed and the approval of the local County Health Dept. We spent the whole summer and fall of 1975 going through all the necessary tests, hearings, meetings with state and local officials and on-site inspections of the composting area.

Since we had been very cautious with the composting done earlier, we were allowed to continue through the summer and fall of 1975 without the written permit from the state. This allowed us to have compost ready to use for the winter and spring of 1976. Our compost mixture now consisted of 2 parts hardwood bark, woodchips and straw, all thoroughly mixed with each other, and 1 part digested sludge. In the fall of 1975 we sent in a sample for testing. The results this time turned out to be excellent: pH 6.4, magnesium 276 (V.H.), phosphate 480 (V.H.), potash 375 (V.H.), soluble salts 720 ppm (low).

Finally, on January 28, 1976, we received a written permit to compost from the State of Maryland. We were convinced by this time that Columbia City's treatment plant was our best source of digested sludge. We also concluded the compost would be at least 1-year-old before being used for planting or top-dressing plants grown in the ground.

At the present time, our composting is done by reversing the pile with a large industrial front-end loader. For the first 2 months, we try to turn the pile 3 times, and then at least once every 3 months for a year. Once the year of composting is complete, it should be covered or stored inside to prevent leaching from rain.

This past year, every plant that went into 1 gal containers or larger had a certain percentage of compost in the mix. We had good results with the 50% top soil and 50% compost mixture and are planning to grow everything in this mix by adjusting the pH to suit the plant. The only exception will be with rhododendron, pieris, and azalea cultivars. We will continue to use an artificial mixture of sand, peat, and bark with 10% composted sludge added.

Here are some factors to consider which I have found to be useful in the successful and safe handling of sludge:

1. Make sure your source of sludge is low in soluble salts, 1500 ppm or lower.
2. The compost pile should generate heat up to 60° to 70°C in order to kill pathogenic bacteria and weed seeds; it also shows that the composting process is working.
3. Location of the composting area is important. You must prevent run-off into streams, lakes and rivers.
4. It is advisable to have no physical contact with the sludge before composting.
5. Machinery should be thoroughly washed immediately after using.
6. Always test the compost before using.
7. Leaves alone do not make a good bulky organic material to compost with.

The work of converting the human wastes and removing their offensive odor is done by microorganisms, which naturally convert wastes into plant food. Such bacteria, fungi and other organisms are an important link in the nitrogen cycle. These microorganisms can recycle human wastes rapidly if given the chance. The sad truth is, though, that the great majority of our wastes are never allowed to meet up with the microorganisms that in nature act as recycling agents. How long are we going to stand by and watch all that good nitrogen, phosphorus, potassium and humus go into landfills, oceans, bays, or into some river? Composting sludge requires some effort, but we feel it pays big dividends by being able to grow quality plant material at a nominal cost.

MARKED GROWTH RESPONSE OF WOODY PLANTS WITH SCREENED COMPOSTED SEWAGE SLUDGE[1]

FRANCIS R. GOUIN

Department of Horticultural
University of Maryland

Nurserymen sell tons of top-soil with balled and burlapped crops and hundreds of cubic yards of potting mix with plants grown in containers. Peat moss, shredded bark, and greenmanure crops have been their primary sources of organic matter, while fertilizers and lime have been their principal

[1] Scientific Article No. A2252, Contribution No. 5244 of Maryland Agricultural Experiment Station, Department of Horticulture.

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sources of plant nutrients. As prices for these materials increase and supplies of peat moss and bark decline, the need for new sources of organic matter and plant nutrients is evident.

Sewage sludge when properly composted with wood chips (1,6) makes an ideal substitute for peat moss as a soil amendment (3) and in potting mixes (5). This dependable source of organic matter, once a public liability, can now be converted into a community asset through composting. Compost made from sewage sludge and wood chips is similar in appearance to a potting mixture of peat moss and pine bark with an odor nearly identical to garden compost. Safe disposal of sewage sludge continues to be an environmental problem, but composting promises to be a practical and efficient method for converting sludge into a usable product. Studies with compost made from municipal waste and sewage sludge look promising (4).

The greenhouse and nursery industry is a logical outlet for compost made from sewage sludge as both of these industries deal with non-food crops and are heavy users of organic materials and fertilizers. Because nursery and greenhouse crops are generally not edible, concern about introducing heavy metals into the food chain is unlikely.

Optimum soil application levels of screened composted sewage sludge made from digested sludge appears to be between 112 to 224 metric tons per hectar(T/ha). Studies with soil-incorporated levels of 0, 112, 224, and 448 (0, 50, 100, and 200 tons per acre) on Evesboro sandy-loam soil just prior to seeding *Liriodendron tulipifera* and *Cornus florida* resulted in increased soil pH, Mg, and P levels in the soil after the first growing season (Table 1). Because sludges are low in K, there was a decrease in the K content of the soil due to crop uptake

Table 1. The influence of screened sludge compost on soil pH, and Mg, P, and K concentrations after one growing season.[v]

		ppm		
Metric tons/ha.	pH	Mg	P	K
Original[w]	5.2 c[y]	9 c	123 b	87a
0[x]	5.2 c	7 c	132 b	39 c
112	6.7 b	70 b	174a	31 c
224	7.1ab	93 b	176a	31 c
448	7.3a	149a	170a	38 c
Compost[z]	6.9	30	230	20

[v] Analysis supplied by Soil Testing Laboratory, Dept. of Agronomy, University of Maryland, College Park, Maryland.
[w] Soil samples taken from the area before treatment in October 1973.
[x] Soil samples taken from each plot in October 1974.
[y] Mean separation for each column by Duncan's multiple range test, 99% confidence level.
[z] pH and nutrient levels of compost used.

and leaching. Although available levels of Mg in the compost were low, there appears to be a rapid release of Mg as it decomposes in the soil.

Equally important were the effects of compost on increasing the water-holding capacity of treated soils (Table 2). The addition of compost to the soil not only increased the water-holding capacity of soils at field capacity, but also increased the amount of water available for plant growth (retention difference, the difference between field capacity and wilting point).

Table 2. The water holding capacity of soils 18 months after treatment with 4 levels of screened sludge compost.[x]

	Percent Moisture		
Metric tons/ha.	*Field capacity* (0.33 bars)	*Wilting point* (15.0 bars)	*Retention* difference
0	9.1[y]	2.2	6.9
112	11.4	2.9	8.5
224	12.2	4.2	8.0
448	15.4	5.0	10.4

[x] Analysis supplied by A. Hart and E. Epstein, Biological Waste Management and Soil Nitrogen Laboratory. U.S. Department of Agriculture, Beltsville Agriculture Research Center, Beltsville, Maryland.
[y] Means of 2 replications.

However, the influence compost had on the soils can best be measured by the growth response of *L. tulipifera* and *C. florida* seedlings grown in compost amended soils. As the levels of compost increased from 0 to 224 T/ha there was a corresponding increase in the number of marketable seedlings harvested (Table 3). Increasing the compost levels to 448 T/ha not only reduced the number of seedlings harvested, but also reduced the total number of marketable seedlings.

Table 3. Mean number of *Cornus florida* and *Liriodendron tulipifera* seedlings in each grade harvested from soil amended with screened compost.

Size[z]	*C. florida* T/ha of compost				*L. tulipifera* T/ha of compost			
(cm)	0	112	224	448	0	112	224	448
0-10	16.0	0.5	0.5	0.5	248.5	47.0	26.5	17.0
10-20	75.0	6.5	3.5	2.0	90.0	67.5	39.0	28.5
20-30	182.5	21.0	11.5	8.0	12.5	81.0	58.5	31.0
30-40	111.5	39.0	24.5	16.5	2.5	66.5	65.0	50.0
40-50	23.5	77.5	44.5	54.0	—	46.5	78.0	45.5
50-60	2.5	151.5	138.5	155.0	—	25.5	52.5	43.5
60-70	2.5	102.0	201.0	78.5	—	12.0	36.0	31.5
70-80	—	4.0	16.5	1.5	—	0.5	15.0	6.5
80-90	—	—	1.0	—	—	—	0.5	3.0

Table 3. (Continued)

Mean number of seedlings	414ab[y]	401abc	441a	316c	353ab	347ab	371ab	258b
Mean stem length	31.6d[y]	56.4b	62.1a	58.7ab	13.3d	33.0b	43.6a	45.7a

[x] Established grades based on stem length in cm from the soil line to the uppermost live bud.

[y] Mean separation for each species by Duncan's multiple range test, 95% confidence level.

— Grade with most seedlings is underlined.

The root systems of both species were altered by the use of compost (Figure 1). *C. florida* plants growing in the 0 and 112 T/ha treatments produced the heaviest and most fibrous roots. Seedlings growing in the 224, and 448 T/ha treatments as well as in adjoining beds growing under a general fertilizer program developed coarse, limited root systems. *L. tulipifera* seedlings developed fibrous root systems in 112 and 224 T/ha treatments (Fig. 2). Seedlings growing in 0 and 448 T/ha, as well as in adjoining fertilized nursery beds, developed coarse, poorly branched roots.

L. tulipifera seedlings growing in compost-treated soils were more winter hardy than seedlings grown in the 0 treatment and in adjoining nursery beds. Seedlings in the compost-treated soils retained their foliage after several frosts while seedlings growing in the 0 treatment and in fertilized beds were

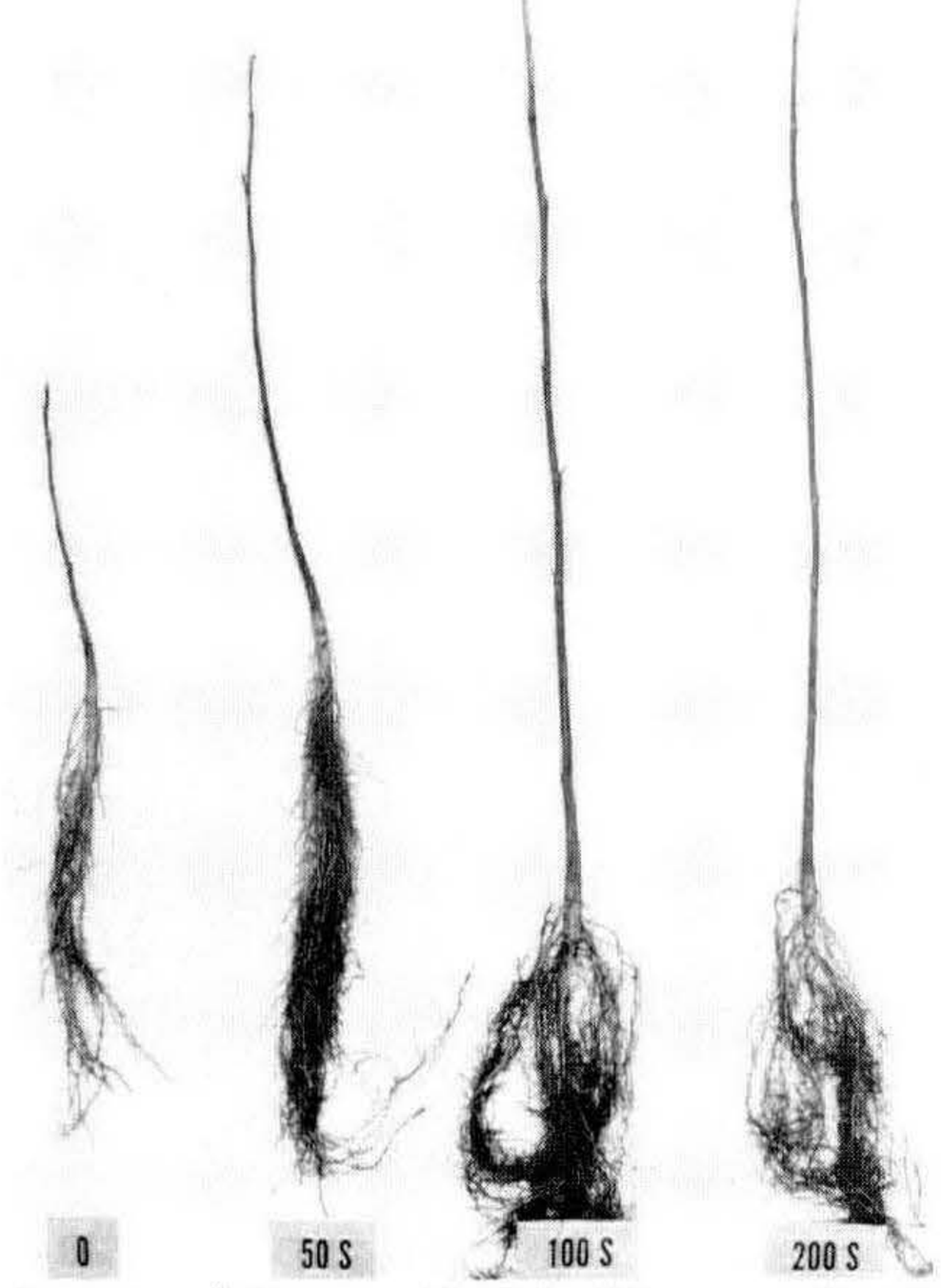

Figure 1. Stems and roots of *Cornus florida* (Dogwood), 16 months after seedings in compost-treated soils. *Soil treatment:* (0) Unfertilized control, (50S), (100S) and (200S), respectively, 112, 224, and 448 T/ha screened composted sludge amendments.

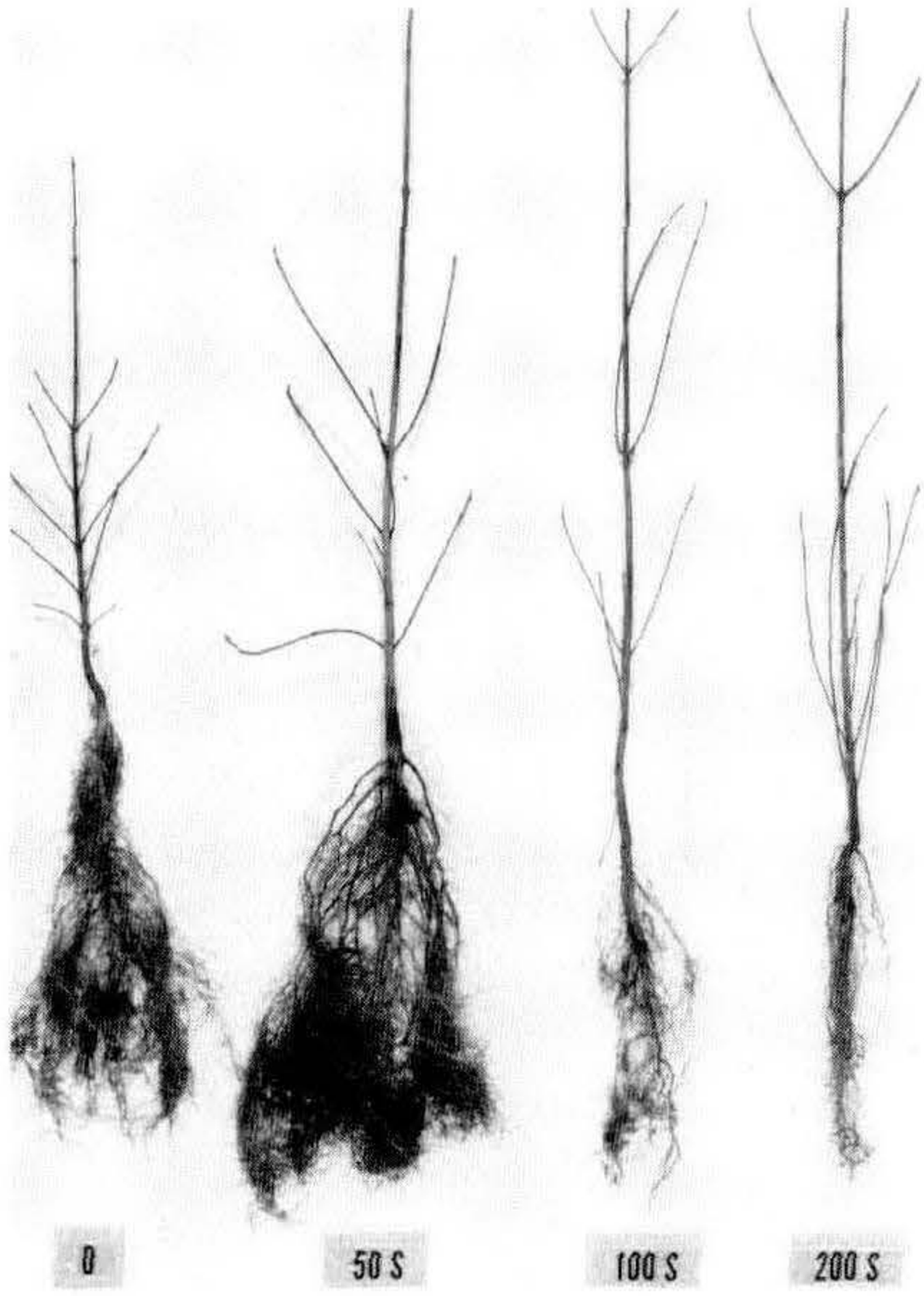

Figure 2. Stems and roots of *Liriodendron tulipifera* (T poplar) 16 months after seeding in composted-treated soils. *Soil treatment:* (0) Unfertilized control, (50S), (100S), and (200S), respectively, 112, 224, 448 T/ha screened composted sludge amendments.

defoliated. In March when the seedlings were harvested and graded, *L. tulipifera* seedlings grown in composted-treated beds exhibited no winter die-back, while seedlings grown in the 0 treatment and in the fertilized beds suffered extensive tip die-back. Increase in the water-holding capacity of the compost and the slow-release of plant nutrients probably accounted for the excellent winter survival observed.

Preliminary studies on the use of screened sewage sludge compost in potting mixes appears promising. Potted rooted cuttings of *Cotoneaster congestus* and *Jasminum nudiflorum* top-dressed with Osmocote 18-6-12 at potting time grew best in a potting mix containing 3 parts screened composted sewage sludge, and 2 parts composted municipal leaves (Table 4) However, by the end of the first growing season only 2/3 of the original potting mix remained in the containers. In the spring, after over-wintering, the containers were only half-full. This loss of the growing medium is primarily attributed to shrinkage due to oxidation. Plants growing in containers filled with 3 parts screened composted sewage sludge and 2 parts sand grew almost equally as well without any noticeable shrinkage in the containers.

To establish Osmocote 18-6-12 fertilizer levels for potting

mixes containing screened sewage sludge compost, a replicated trial with *Ilex crenata* 'Buxifolia' was conducted using 3 potting mixes (Table 5). The results indicate that Osmocote levels of 252 g/35.2 liters (9 oz/bu) appear to be near optimum (2). Additional studies are currently being conducted to further evaluate the use of composted sewage sludge for container-growing of ornamental plants.

With increased national emphasis on cleaning up the environment and recycling, it is likely that compost made from sewage sludge will become a readily available material near municipalities, with sludges that are low in heavy metals, within a few years. Several communities are already composting sewage sludge with wood chips, and many more are expressing considerable interest. The possibility of composting sewage sludge with other muncipal waste also looks promising and feasible. The nursery and greenhouse industries appear to be suitable users of this product without the fear of accumulation of heavy metals in soils or in food crops.

Table 4. Growth response of *Cotoneaster congesta* and *Jasminum nudiflorum* growing in 15 cm (6 inch) plastic containers filled with 3 different potting mixes top-dressed with 14 gr (1/2 oz) of Osmocote 18-6-12 per container.

	Total stem length in cm[x]		
species	3 compost 2 leaves	3 compost 2 sand	3 leaves 2 sand
C congesta	342	324	309
J. nudiflorum	378	316	310

[x] Means of 3 replications with 3 plants per replication.

Table 5. Growth response of *Ilex crenata* 'Buxifolia' growing in 15 cm (6 inch plastic containers filled with 3 different potting mixes with 4 levels of Osmocote 18-6-12 fertilizer incorporated in each mix.

Potting mix by volume	18-6-12 Osmocote oz/bu or g/35.22 L		Mean total stem length[x] in cm	
3 composted sewage sludge	0	0	30.9 b[y]	
2 sand	3	84	42.7 b	50.4 a
	6	168	56.9 ab	
	9	252	71.1 a	
2 composted sewage sludge	0	0	33.4 b	
1 leaf compost	3	84	46.0 b	55.2 a
2 sand	6	168	59.8 ab	
	9	252	81.6 a	
1 composted sewage sludge	0	0	25.2 b	
2 leaf compost	3	84	33.8 b	43.3 a
2 sand	6	168	43.0 ab	
	9	252	71.4 a	

[x] Means of 3 replications with 5 plants per replication.
[y] Mean separation for each column by Duncan's multiple range test, 95% confident level.

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TEMPERATURE RELATIONSHIP IN ROOT INITIATION AND DEVELOPMENT OF CUTTINGS[1]

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Optimum temperatures for rooting of cuttings have long been accepted to be in the range of 20 to 25°C. Many studies have been carried out to support this assumption (2,5). However most studies on rooting temperatures have involved only one evaluation — that of root development after a set time period. Few studies have actually looked at root initiation and root development as two separate plant processes. Likewise, few workers have noted the time required for root initiation at different temperatures and actual root numbers initiated at different temperatures.

Hartmann and Kester (2) state that 21°-27°C day and 15°C night is optimum for most plant species. Below 21°C rooting is reduced and slowed down. At temperatures of 23°-27°C root inhibition often occurs as well as root injury. Howard (4) has shown that easily-rooted plum cuttings root best at 20°C. However, he noted that shy-rooting clones root more readily at 25°C.

A few workers throughout the last 50 years have looked at root initiation and root development as two separate processes in regard to temperature response. Sykes (8) showed that at temperatures of 30°-33°C, hop cuttings showed little delay in callusing and development of small roots, but these roots failed

[1] Michigan Agricultural Experiment Station Journal Article No. 7649.

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to extend. He concluded that the optimum temperature for rooting was 22°C and that supra-optimal temperatures appeared to inhibit root development without adversely affecting initiation. Howard (3), also worked with hops, found that at 27°C roots emerged in 4 days whereas at 22°C, no emergency occurred until the 10th day. Also cuttings required 6 days to obtain 10 roots per cutting at 27°C whereas 17 days were required at 22°C.

Work carried out in the Netherlands in 1927 (9) separated the temperature response of these two processes. The highest root count with hyacinth bulbs occurred at 27°C within a temperature range of 12.5°-27°C. However, root extension was greater and faster at 17°C and at all lower temperatures. It appeared that the greatest root initiation took place at 27°C but subsequent root elongation was greatest at 17°C.

Nightingale (6) working with apple and peach roots found that the greatest fresh weight of roots was obtained at 15°C, and root quality decreased as temperature increased. However callus and root formation was greatest at 30°C, but cells did not live as long at this temperature as at 25°C or less.

To understand how temperature affects root initiation and root development it is necessary to look at the two processes involved. Root initiation is basically cell division. Initiation is controlled by the rate of cell division and by the number of cells dividing. Root development, herein defined as that part of root growth subsequent to initiation, includes cell elongation and differentiation as well as cell division. Burholt (1) found that the maximum growth rate of sunflower roots occurred at 25°C. At higher temperatures this rate decreased and completely stopped at 37°C. The actual cell division continued to increase after 25°C and reached a peak between 30°-35°C. However, 25°C was the point which gave the maximum cell size and cell elongation. Above 25°C cell division continued to increase but cell size and the number of cells dividing decreased. This information indicates that total root growth may have two optimum temperatures, one for initiation and one for root elongation.

Preliminary studies by the author to determine the optimum temperature for air-rooting of cuttings suggested that root initiation would occur at temperatures as high as 35°C. Experiments were set up to study the effect of temperature on rooting of cuttings.

METHODS AND MATERIALS

Experiments were carried out using high humidity polyethylene chambers within larger growth chambers. Cuttings were rooted in air so that root initiation and development could be more readily observed and tabulated. Humidification was

supplied by Bete PT10 atomization nozzles suspended above the cuttings. Cuttings were washed in Captan solution and basal ends were treated with 1000 ppm IBA in talc before placing in the rooting chamber. All cuttings were suspended utilizing polystyrene strips through which the cuttings were placed in prepunched holes. Entire cuttings were exposed to the treatment temperatures.

Each temperature trial consisted of 2 temperature with four blocks per temperature and 10 cuttings per block in a split block design. Temperatures were provided by two separate growth cabinets. Humidity and lighting were kept equal in each chamber. Trials were carried out with *Chrysanthemum* × 'Bright Golden Anne' cuttings, under a 16 hour lighting period.

A range of temperature combinations were evaluated. These included the following combinations: 1) 22° and 35°C; 2) 30° and 35°C; 3) 25° and 30°C, and 4) 25°, 30°C and 30° until emergence, then 25°C. Combinations 2, 3 and 4 were replicated in time to allow for statistical analysis. Cuttings were evaluated for the number of days to root emergence, number of roots per cutting, and degree of rooting.

Degree of rooting was determined on a scale of 0 to 5: 0 — no rooting; 1 — slight root emergence; 2 — a few roots developing; 3 — several roots developing; 4 — many well developed primary roots, and 5 — well developed roots with secondary branching.

In addition to chrysanthemums, cuttings of *Forsythia* × *intermedia* 'Lynwood' were rooted at 30°C and 25°C. The experimental design was the same except it was not replicated in time.

Root and root hair development was studied at various temperatures using a low power microscope.

RESULTS

Chrysanthemum. 22° versus 35° temperature: Roots at 35° emerged quicker and were greater in number than roots at 22°. Roots at 22°, however, showed more rapid root elongation and a far greater number of root hairs. Roots at 35° tended to deteriorate after several days at this temperature and new growth was very slow. Roots at 35° were superior to roots at 22° in terms of mass and number on day 15 (Table 1). However, subsequent to this, roots at 22° rapidly surpassed 35° roots in root elongation, mass and quality.

30° versus 35°C temperatures. The roots on 30° cuttings emerged 1 day earlier than roots on 35° cuttings and the root number was significantly higher at 30°. The "degree of rooting"

taken on day 9 of the second trial was greater for 30° than for 35° (Table 1).

Roots on cuttings at 35° grew to 1 cm in length and then appeared to stop. New root growth turned brown within 2 days at 35°. Root hairs did not develop at this temperature.

Roots at 30° grew considerably faster than those at 35°. However, roots at 30° as well, turned brown after 4 days or more exposure to this temperature. Root hairs which initially were well developed tended to deteriorate after the second day. It was clear that 35° was beyond the optimum temperature for both root initiation and root development for chrysanthemum cuttings.

Table 1. Rooting of *Chrysanthemum* × 'Bright Golden Anne' at various temperatures.

Temperature	Degree of rooting	No. of roots/cutting
22°C	1.3	
35°C	2.1	
30°C	2.9	15.3 a*
35°C	2.3	8.8 b

* Means followed by the same letters are not significantly different at the 1% level of the L.S.D. Test.

25°C versus 30°C temperatures. Root emergence during these trials was 2 days earlier at 30° than at 25°. Both number of roots per cutting and the degree of rooting was greater at 30° than at 25° when taken on day 10 (Table 2). The final root count per cutting on day 21 was also greater at 30°. However, the final length and mass of roots was greater at 25°.

Root elongation was much greater and root hairs were shorter and thicker at 25° than at 30°. Root hairs at 25° lasted for extended periods of time, whereas at 30° root hairs deteriorated within 2 days of development.

At 30° roots elongated to a maximum of 1.5 cm in 21 days of rooting with considerable dieback of root tips. Roots at 25° were up to 3 cm in length by the 21st day and secondary branching was developing. Subsequently the final root weight per cutting was much greater at 25° than at 30°.

25°C and 30°C versus 30°C until emergence followed by 25°C. Because of the early results of 25° and 30° comparisons a third treatment was utilized in the last two trials. Cuttings were kept at 30° until root emergence and then transferred to 25° for root development. Under this treatment the number of roots per cutting remained the same as for those at constant 30°. (Table 2) This suggested that all roots were initiated prior to the first root emergence.

Table 2. Effects of temperature on root initiation and development in cuttings of *Chrysanthemum* × 'Bright Golden Anne'.

Temperature	Degree of rooting			No. roots per cutting			Days to Emergence	Fresh Wt. roots (mg/cutting)
	Time I	Time II	Ave.	Time I	Time II	Ave.		
25°C	1.6	2.9	2.2a*	12.6	5.8	9.2a	8	341.3
30°C	2.2	3.4	2.8b	20.7	9.2	14.9b	6	269.5
initiated 30°C developed 25°C				20.9	10.5	15.9b	6	539.3
Coef. Var.			17.5%			18.0%		

* Means in the same column followed by the same letters are not significantly different at the 1% level of the F test and HSD test.

However, the final root size of the transferred cuttings differed greatly from those at constant 30° and also from those at 25°. The roots of transferred cuttings grew as rapidly as those at constant 25°. Since the transferred cuttings had a significantly greater root number, the final root weight per cutting was much greater.

Forsythia. The number of days to 50% root emergence was recorded for forsythia (Table 3). It was found that at 25°, forsythia required 13 days for roots to emerge whereas at 30°, roots emerged in 9.3 days. The number of roots initiated at 30° was much greater than those at 25°. Roots at 30° however, were smaller in diameter and lacked root hair development.

Table. 3. The effects of temperature on the rooting of *Forsythia* × *intermedia* cuttings in air.

Temperature	Days to 50% rooting	No. roots per cutting	
		Day 15	Day 20
25°C	13.0	2.4	5.2
30°C	9.3	6.2	9.1

DISCUSSION

The rooting response to temperature was very similar in both chrysanthemums and forsythia. The high temperature of 30°C resulted in more rapid root initiation, shorter emergence time, and more roots per cutting. However, subsequent root development including elongation, diameter, and root hair development; secondary branching occurred more readily at the lower temperature of 25°C. This supports the concept that roots have two optimum temperatures for total growth, one for initiation and one for elongation and development.

When cuttings are subject to both of these optimum temperatures in sequence, total rooting time can be reduced significantly and the final root size will be greater than for cuttings held constant at either a high or low temperature.

An optimum temperature graph for root initiation and development is proposed (Figure 1). This graph, based on these studies, is offered as a generalized temperature relationship to the rooting of many plant species.

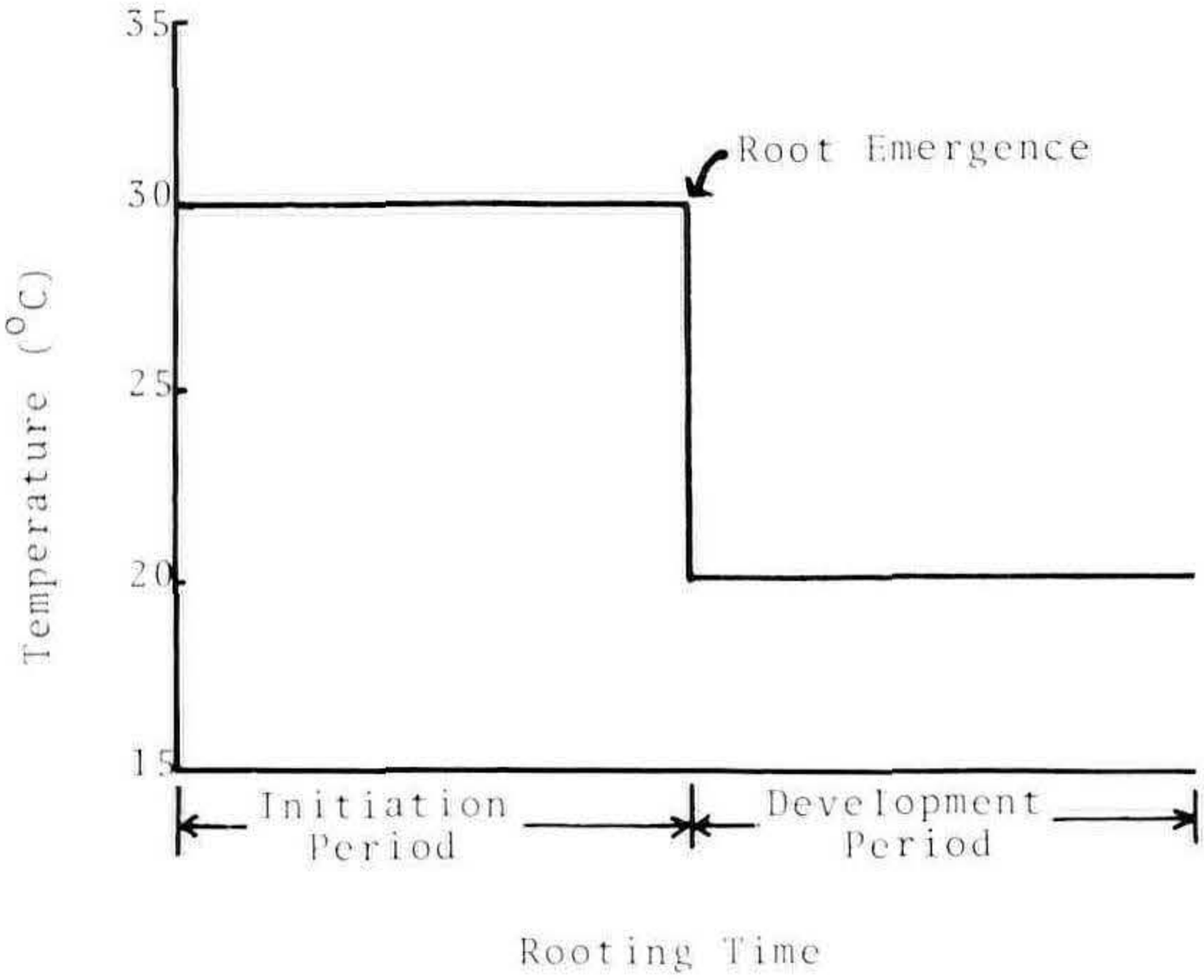

Figure 1. Proposed temperature regime for maximum rooting of cuttings of many plant species.

These studies have not pinpointed the optimum temperatures for any one species but have merely shown that the two rooting processes respond to different temperatures. In the past, propagators have realized this point, but have failed to utilize this knowledge. It is suggested here, that propagation time may be reduced significantly by providing the optimum temperature for each rooting process.

Even with the two readily rooted species used in these studies, emergence time was reduced by 30% and root number was increased by 60% to 80%. Howard (4) states that difficult-to-root species respond more to increased temperature than easily-rooted species.

The reason for the increased rate of initiation at the higher temperature is not entirely clear. Burholt (1) suggested that the rate of cell division increase to a maximum between 30° and 35°C. This alone may be the sole explanation. But we also observed that plants are much more responsive to auxin at the higher temperatures. The advantage of auxin application over no auxin was far greater at 30° than at 25°C. It has also been noted by Scott (7) that auxin activity in roots is much greater at higher temperatures. Since we are still unable to explain the role of auxin in root initiation it is difficult at this time to tie these two processes of mitotic cell division and increased auxin activity together.

SUMMARY

Cuttings of both chrysanthemums and forsythia were shown to have maximum root initiation at 30°C. Maximum root development including elongation, diameter, root hair development and secondary branching was shown to occur at temperatures below 30°C (25°C in these experiments). The greatest total root growth in chrysanthemums occurred when roots were initiated at 30°C and allowed to develop at 25°C.

It is proposed that root growth of most species, if not all, can be divided into two processes, root initiation and root development, each having a temperature optima. From the results of these studies and from the literature, it appears that the optimum temperature for root initiation of many species is in the area of 27° to 33°C. Whereas the optimum temperature for root development may be lower, in the range of 17° to 25°C. It is proposed that significant advantages in terms of rooting time and root quality may be gained by utilizing a two temperature system in the rooting of cuttings.

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NUTRITION OF ORNAMENTAL CROPS[1]

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Nutrition of ornamental crops is a complex problem. For example, Brewer (2) reported containerized *Ilex crenata* growth was maximized with 400 ppm N, 15 ppm P, and 120 ppm K in the irrigation water. Gouin and Link (7) reported growth of containerized *Taxus* × *media* 'Hatfieldii' was maximized at 224 ppm N, 75 ppm P, and 135 ppm K. Plant materials grown in nursery operations are diverse, the nutritional factors which result in growth maximization of one plant type often do not produce equivalent results with others.

Leibig in 1843, developed what has become known as the "Law of the Minimum." The law states that, if any essential element is deficient with all others at optimum levels, growth is controlled by the deficient element. This premise holds for any essential component of the cultural system (light, water, temperature, pH, drainage). Thus growers may be employing similar nutritional practices yet obtaining different growth results because other cultural factors are limiting.

Response from Nurserymen. A questionnaire to determine fertilization practices of ornamental plants (3,4) showed that of 45 nurserymen responding, 18% grew ground covers, 87% evergreens (narrow and broadleaf), 70% deciduous shade trees, 66% deciduous shrubs, and 61% small to medium-sized ornamental trees. Of these, 18% grew one group of plants, 9% two, 20% three, 33% four, and 20% five. Most nurserymen grow many types of woody plants and cannot maximize growth with a single nutritional regime.

The growing systems used included field production (59%), containers (10%), or a combination (31%). The total acreage in field production was 20,534 while container production was about 25,000,000 cans per year.

A regular fertilizer program was used by 91% while 9% had no program. With respect to determining when and in what quantities to fertilize we found that no one used plant analysis alone, 58% used soil analysis; 18% used plant and soil analyses and half of those were from Ohio nurseries. There were 19% who fertilized when time permitted, while 5% applied fertilizer when they thought the plants needed it. A fertilization program can be based on either soil or tissue analysis. Due to the wide-

[1] Supported by Illinois Agricultural Experiment Station.

spread access to soil testing laboratories, soil analysis is most commonly used by nurserymen.

Most nurserymen (83%) applied elements other than N and indicated a definite benefit was derived from this practice. The principal elements applied were P, K and Fe but 17% applied only N and, in fact, could not see any benefit in increased growth or appearance with other essential elements. This 17% constituted field production operations where immediate responses are not always evident.

Over half (52%) reported that excess soil salinity and pH did not present cultural problems. However, 29% (all container growers) indicated excess salts could be or were a significant problem. The pH presented a cultural problem to 11% and 8% had no idea if these factors were affecting growth.

A diversity of nitrogenous fertilizers is used by nurserymen. Ammonium nitrate, urea, and 20-20-20 were reported as used most frequently. Many nurserymen use a "complete" fertilizer and the N carrier is usually mono- (11-48-0) or di-(18-46-0) ammonium phosphate. The higher analysis granular or water soluble fertilizers are often composed of ammoniated phosphates, NH_4NO_3 and/or urea. One Ohio nurseryman noted that "growers might take a close look at costs versus N source, it can be shocking." The lowest priced N source is anhydrous ammonia yet growers tend to avoid it. Special application equipment is required and there is the possibility of injury to plants. However, an Illinois nurseryman has successfully adopted anhydrous ammonia into his cultural program. He noted the spring flush of growth was not as pronounced as with NH_4NO_3 but over the entire growing season the results from each source proved equal. The reason for the slow growth in spring from anhydrous fertilization is the reduced conversion rate of NH_4-N to NO_3-N. This does not occur rapidly until soil temperatures reach the 60°F plus stage.

It becomes difficult to compare the degree of growth on similar plant types from operation to operation simply because of the great differences in cultural and fertilizer programs. The quantity of N applied to nursery stock varied tremendously. For example, at the low range field-grown yews and junipers received 20 lb N/A/year while ornamental shade and flowering trees received 250 lb N/A/year. The average range for field crops was 75 to 100 lb N/A/year. For container plants, the low rate was 75 ppm N/watering and the high rate 300, these two rates were both used for juniper. The average range was 150-200 ppm N/watering. Variable container fertilization rates are often due to the medium employed; a bark mix has a higher N requirement than a peat:sand mix.

Half of the respondents thought growth was maximized by the cultural and fertilizer practices they employed; 37% said growth had not been maximized and 13% did not know. Half were not confident of their fertilization practices and the results obtained. When growth is not maximized, time, land, labor and supplies are partially wasted and maximum dollar turnover is not realized.

The questionnaire and the literature indicated neither nurserymen nor researchers have adequately studied the effects of mineral nutrition on woody ornamental plant growth and quality. The diversity of plants and the myriad production techniques prohibit defining optimum nutritional levels for every plant type. One nurseryman succinctly summarized the state of woody plant mineral nutrition by noting that he and other nurserymen were "struggling and attempting to find the best fertilizer combinations; perhaps more of an art than science. Probably stumble and stay locked in some of the shotgun methods we are using."

Nutrition and Plant Hardiness. Reduction of cold hardiness has been associated with excess N applications especially those applied late in the growing season but researchers have been unable to show any positive correlation between the factors (4). *Cotoneaster divaricatus*, *Forsythia* × *intermedia* 'Beatrix Farrand', and *Viburnum plicatum* var. *tomentosum* grown in sand culture and fertilized with KNO_3, $Ca(NO_3)_2$, NH_4NO_3, 20-20-20, urea or $(NH_4)_2SO_4$; at 100, 200 or 400 ppm every watering produced the greatest growth with NO_3-N alone. The plants were NO_3-N combinations and finally NH_4-N alone. The plants were then hardened off and subjected to freezing temperatures. Those grown with NH_4-N alone or NH_4-N plus NO_3-N were more severely injured than those grown with NO_3-N alone. The 400 ppm N rate also resulted in greater freezing susceptibility than the lower rates. In a field study *Cornus sericea* forma *baileyi*, *Forsythia* × *intermedia* 'Spring Glory', and *Juniperus chinensis* 'Hetzii' were fertilized with either 2, 4, 6, or 8 lb N/per 100 sq ft using NH_4NO_3, $Ca(NO_3)_2$, urea, or 12-12-12. In the following spring the plants were rated for frost injury. *Forsythia* was injured at the highest N rate regardless of source but no injruy was apparent on *Cornus* or *Juniperus*.

It is difficult to extrapolate the results of greenhouse studies to field studies. The standardization of fertilizer and cultural practices within the nursery industry is impossible because of the great diversity of plant material and cultural systems, as well as the wide latitude of climates in which many plants are grown. Improvements can be made in the present fertilizer and cultural systems that will be of significant economic benefit to the nurseryman. In many repsects the most applicable

research is that conducted by each nurseryman and the subsequent gearing of the successes and failures to improve his particular system.

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HYPOBARIC STORAGE — AN OVERVIEW

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Hypobaric or low pressure storage (LPS) is a relatively new technology that may significantly alter many production and/or marketing procedures presently being used in horticulture. It is the purpose of this paper to briefly introduce LPS by discussing the history, principles, capabilities and present status of this technology.

History. The storage of horticultural commodities and other perishables is limited by pathological and/or physiological disorders. Of major concern is the influence of carbon dioxide,

research is that conducted by each nurseryman and the subsequent gearing of the successes and failures to improve his particular system.

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History. The storage of horticultural commodities and other perishables is limited by pathological and/or physiological disorders. Of major concern is the influence of carbon dioxide,

ethylene and other gases on commodity longevity. For example, it has been well documented that ethylene can promote many detrimental processes that can reduce commodity usefulness (5).

Studying fruit storage in 1965, Burg and Burg (8) observed that if gas exchange (i.e. CO_2, ethylene) from within the fruits to the atmosphere was enhanced, storage longevity increased. Expanding this concept, Burg and his associates developed LPS and have had two U.S. patents issued (4,10). After extensive research especially by Burg (6,7,9,10), Dilley (11-15), and their co-workers, LPS units are presenting being manufactured commercially in the U.S.

Principles. Low pressure storage consists of placing various commodities in a flowing stream of air essentially saturated with water at a controlled temperature and under reduced pressure. Under these conditions, the partial pressure (amount) of oxygen is decreased which results in a reduction of metabolic activities like respiration and commodity longevity is increased. Of possibly more significance is the rate at which gas exchange (diffusion) is increased at reduced pressures. At 1/10 atmosphere, gas diffusion is increased by a factor of 10 compared to atmospheric pressure. By having a continuous exchange of air, gases like CO_2 and ethylene being produced by the stored commodities are removed from the storage area before they can influence longevity.

Besides reducing oxygen levels and enhancing gas diffusion, the LPS system was so designed as to maintain high humidity which reduces weight loss and/or desiccation. Adding water vapor to the air stream passing through the storage area is accomplished by passing air through a water phase *after* the pressure has been reduced.

Low pressure storage units do not have to operate continuously to be effective. In fact, often added advantages in commodity longevity are noted when the units do not operate continuously.[1] Thus, LPS units may be opened daily or whenever desired. In summary, increased gas diffusion, reduced metabolic activities, proper temperatures, and high relative humidity all help enhance commodity longevity when held under IPS.

Capabilities. Data presented in Table 1 demonstrates the broad capabilities of LPS for the storage of various perishable commodities. The vast majority of data was compiled by Burg, Dilley, Carpenter and their co-workers (6, 7, 9-15).

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[1] Personal communication from S.P. Burg, 1976.

Table 1. Comparative storage lives of commodities stored under normal refrigerated or hypobaric conditions.

RIPE, FULLY MATURE FRUIT

Type	Storage Life - Days	
	Cold Storage	Hypobaric Storage
Pineapple (field ripe)	9-12	30-40
Strawberry, 'Florida Ninety' and 'Tioga'	5- 7	21-28
Cherry, sweet	14	60

VEGETABLES

Type	Storage Life - Days	
	Cold Storage	Hypobaric Storage
Green pepper	16-18	35-49
Cucumber	10-14	35-42
Bean, pole	10-13	30
Onion, green	2- 3	15+
Corn	4- 8	21-28
Lettuce, 'Iceberg'	14	40-50
Mushroom	1- 2	21-28

NON-RIPE, FULLY MATURE FRUIT

Type	Storage Life - Days	
	Cold Storage	Hypobaric Storage
Tomato, 'Mature Green'	14-21	60
Tomato 'Breaker'	10-12	28-35
Banana, 'Valery'	10-14	90-150
Avocado, 'Lula'	14-28	52-84
Lime, 'Tahiti'	14-35	60-70
Apples (general cultivars)	10-90	300
Mango	7-14	28
Papaya	7-14	21-28

FLOWERS / CUT

Type	Storage Life - Days	
	Cold Storage	Hypobaric Storage
Carnation	10	91
Chrysanthemum (bud cut)	7-14	42
Rose	7-14	56

CUTTINGS

Type	Storage Life - Days	
	Cold Storage	Hypobaric Storage
Non-rooted cuttings:		
Chrysanthemum (numerous cultivars)	10-28	42-94
Carnation	90-120	300
Rooted cuttings		
Chrysanthemum	7-14	90

In addition to increasing storage life, commodites held under LPS often exhibit beneficial characteristics after removal under standard conditions. For example, with some crops after removal from LPS, ethylene production is delayed (14). The delay in ethylene production partially accounts for such crops actually having greater longevity after LPS compared to freshly harvested crops. A second example deals with a disorder in roses called "bent neck". This disorder results in a severe bending or wilting of the flower stem immediately below the inflorescence. Unpublished research by this author and by Dilley and Carpenter indicates that very short low pressure treatments immediately after harvest can greatly reduce subsequent bent neck of roses.

Status. The present state of the art is that Grumman Allied Industries of Garden City, New York, has purchased the rights to the LPS patents and is presently constructing commercial units. These units can be used as over-the-road trailers or as containers for sea or train transportation and are of comparable size to standard refrigerated units now in operation. Of the LPS units already being used commercially, no major mechanical problems have been experienced and the various products being stored and/or transported all have been of exceptional quality upon removal.

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LOW PRESSURE STORAGE OF ROOTED AND UNROOTED GERANIUMS

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Abstract. Unrooted and rooted geranium (*Pelargonium* × *hortorum* L.H. Bailey.) cuttings were stored for 2, 4 and 6 weeks utilizing a low pressure (LP) storage system maintained at 2.2°C. Unrooted cuttings stored at 1/30 atm were of acceptable quality after 2, 4 or 6 weeks of storage and rooted equaled cuttings directly rooted without storage. Rooted cuttings removed after 2 and 4 weeks of LP storage were acceptable while similar material removed from common cold (CC) storage were unacceptable. In all cases LP storage extended the life of rooted and unrooted geraniums when compared to CC storage.

Many rooted and unrooted cuttings stored for extended periods show reduced rooting and deterioration of foliage. A new storage system termed hypobaric, sub-atmospheric or low pressure storage (LPS) offers a means for long-term commodity storage while preventing post-storage breakdown.

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Many rooted and unrooted cuttings stored for extended periods show reduced rooting and deterioration of foliage. A new storage system termed hypobaric, sub-atmospheric or low pressure storage (LPS) offers a means for long-term commodity storage while preventing post-storage breakdown.

Reasons to implement LPS will vary from operation to operation; however, the ability to store rooted and unrooted cuttings for long periods could be advantageous to a producer in numerous ways. First, since more cuttings can be stored in a smaller area, it allows for increased bench space. Secondly, successful LPS would allow a grower to store cuttings taken prior to a peak season and when sales increase, remove the cuttings stored under the LP system and sell them along with additional cutting material obtained from his stock plants. Thirdly, if a producer has propagation material at the optimum condition and is not prepared to propagate it, he could store it until facilities or conditions improve.

Research involving storage of rooted and unrooted cuttings is limited. Pryor and Stewart (2) successfully stored unrooted softwood azalea cuttings for 10 weeks at -0.5°, 1.7°, and 3.9°C (31°, 35°, and 39°F) with the rooting response equal to non-stored control cuttings. Flint and McGuire (1) stored 31 species of rooted cuttings for 6 months at 1° and 4°C (32° and 40°F). Eighteen of the 31 species tested had a survival rate of 75% or greater. Snyder and Hess (3) were unsuccessful in obtaining adequate growth from *Juniperus communis* 'Hibernica', *Thuja occidentalis* 'Pyramidalis' and *Thuja occidentalis* 'Globosa' after 139 days of storage at -0.5°, 1.7° or 3.9°C. *Taxus cupidata* at 3.8°C were in excellent condition upon removal from storage and subsequent growth was equal to the controls.

Low pressure storage has not been used for commercial storage of woody cuttings as the system is relatively new and untested for this purpose. Studies have shown that the storage life of chrysanthemum, carnation, and geranium can be extended 66, 210, and 23 days respectively, using LP as compared to CC storage.[1] Rooted cuttings of chrysanthemums were successfully stored 90 days using LP as compared to 14 days with CC storage.[1]

Rooted and unrooted geraniums have a limited storage life in CC storage. Thus studies were initiated to determine if the storage life of unrooted and unrooted geranium cuttings could be extended using LP storage. In addition, pre and post harvest handling procedures were investigated.

MATERIALS AND METHODS

All plant materials were stored in 38.0 liter stainless steel milkcans lined with 1.9 × 1.9 cm/steel mesh. Low pressure chambers were sealed so that lids were air tight. Air was removed with a vaccum pump and the pressure was maintained

[1] Personal communication from S.P. Burg, 1976.

with Matheson 49 pressure regulators. Chambers were maintained at 1/30 atm with 1 air exchange per hr. Relative humidity was maintained between 95-98% by passing the air at reduced pressure entering the chamber through a water bath. Common cold storage cuttings were placed in milkcans with 95-98% relative humidity at atmospheric pressure. In all experiments, temperature was maintained at 2.2°C (36°F) and plants were stored in the dark.

Unrooted geranium cuttings were taken from stock plants immediately prior to being placed into storage. Cuttings were submerged for 30 sec in a 1 tbs/gal Daconil mixture and allowed to dry before placing in loosely sealed polyethylene bags and stored for 2, 4 or 6 weeks. Upon removal from storage, cuttings were rooted in 1:1:1 (v:v:v) peat, perlite, sand medium under a 6 sec/6 min mist cycle for 25 days. Parameters measured were foliage condition at removal and foliage and roots after rooting.

Rooted geranium cuttings received a thorough Daconil spray (1tbs/gal), allowed to dry, then placed directly into storage chambers for 2, 4 or 6 weeks. Plants were either stored under CC and LP storage. Upon removal from the storage systems, plants were placed under mist for 2 days, then removed from mist and placed in a 28°C greenhouse for 12 days. The experiment was terminated at that time and final foliage characteristics were recorded.

Scales used for evaluation of foliage and roots were as follows:

Foliage Evaluation
0 - dead
1 - all leaves yellow and deteriorating
2 - all leaves yellow
3 - majority of leaves yellow
4 - 1 or 2 leaves yellow
5 - all leaves green

Rooting Response
0 - dead
1 - callus
2 - callus with few roots
3 - light
4 - medium
5 - heavy

RESULTS

Unrooted cuttings. Unrooted cuttings of geraniums from LP storage were of acceptable quality at removal from the chambers and following 25 days in the mist bed (Table 1). Only cuttings of material stored for 2 weeks in the CC system were of acceptable quality while cuttings stored 4 and 6 weeks showed terminal dieback, basal rot and yellowing. Material stored in the LP system showed some marginal yellowing on cuttings removed after 4 and 6 weeks storage, but the yellowing did not further develop.

Rooting of cuttings stored in the LP system at all removal

dates was acceptable. Cuttings removed from CC storage after 2 weeks rooted, however, material stored 4 or 6 weeks either died in the mist bed or showed poor root development (Table 1).

Table 1. Visual evaluation of unrooted geraniums at removal and 25 days following removal from LP or CC storage.

	Low Pressure Storage[1]			Common Cold Storage		
Weeks	Foliage at removal	Foliage 25 days after rooting	Rooting response	Foliage at removal	Foliage 25 days after rooting	Rooting response
2	4.9	4.6	4.5	3.3	4.3	4.3
4	4.6	3.9	3.8	1.6	2.0	1.7
6	3.9	4.0	4.2	0.3	0.0	0.0

[1] See text for explanation of rating scales.

Rooted cuttings. Rooted geranium cuttings stored for 2, 4 and 6 weeks in a LP storage system were of acceptable quality at removal, but quality decreased at each date. Material from the 6 week LP storage treatments, however, were not acceptable when evaluated 14 days later and exhibited severely chlorotic and/or necrotic areas on the stems and leaves (Table 2). Rooted geraniums from the 4 week LP storage treatment yellowed following removal fromt e chambers but new growth was acceptable. Cuttings stored in conventional CC storage units were of acceptable condition after 2 weeks of storage, while similar material stored for 4 and 6 weeks were either completely yellow or diseased.

Table 2. Visual foliar evaluation of rooted geraniums at removal and 14 days following removal from LP or CC storage.

	Foliar Evaluation[1]			
	Low Pressure Storage		Common Cold Storage	
Weeks	At removal	14 days following removal	At removal	14 days following removal
2	5.0	3.8	3.5	3.0
4	4.2	2.4	1.4	1.8
6	4.0	1.4	0.0	0.0

[1] See text for explanation of rating scales.

DISCUSSION

As a result of these experiments, 4 week storage of rooted and unrooted geraniums appears possible utilizing a LP system. Although in the experiment reported here we achieved acceptable results with unrooted cuttings stored 6 weeks under LPS, some difficulty has been experienced in reproducing similar results.

Due to lack of research involving storage of cuttings under LP storage conditions, symptoms such as marginal yellowing, dieback of older foliage and wilting can not be completely explained. Marginal yellowing which occurred on rooted and unrooted cuttings can be limited by placing cuttings under mist promptly after their removal from the LP chambers. In addition, increasing the mist cycle for the first 2 days after removing unrooted cuttings from the LP chambers appears beneficial in preventing wilting.

The better quality of cuttings noted when intermittent mist is applied promptly after the storage period, may be related to vapor pressure deficit (VPD). When cuttings are in the LP chambers, temperature is reduced and relative humidity is maintained at approximately 95-98%. Following removal from the LP system, the cuttings are placed at room temperature (27°C) where the relative humidity is not controlled. Research has shown that if one maintains the temperature at 2.2°C and only readjusts the relative humidity from 90 to 50%, water vapor will escape from the plant 5 times faster (4). If temperature is increased to 21°C with a relative humidity of 70%, water vapor escapes 10 times as fast from foliage as compared to 2.2°C at 90% relative humidity. As a result increasing the mist cycle immediately after removing the cuttings from the LP chambers has resulted in preventing the excessive wilting noted in preliminary experiments.

Cuttings stored under CC consistently showed diseased foliage and basal rot even though they received a fungicide treatment prior to storage. Yellowing caused by chlorophyll breakdown proved to be another limiting factor in CC storage. The low oxygen levels in LP storage may prevent symptoms of this nature from occurring (5). In addition, the removal of ethylene and other volatile gases when using a LP system may also aid in extending the storage life of rooted and unrooted geraniums.

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NEW PLANT FORUM

Mr. William Flemer III served as moderator for the new plant forum.

Dr. Elwin Orton of Rutgers University showed slides of five hollies which he has developed. These are being introduced to the trade as *Ilex* 'Green Dragon', *I.* 'Dwarf Pagoda', *I.* 'Harvest Red', *I.* 'Autumn Glow' and *I.* 'Jersey Princess'. Andy Knauer showed slides and discussed *Idesia polycarpa*. Jim Wells showed slides of *Magnolia* 'Leonard Messel', deciduous azaleas, *Rhododendron* 'Pink William', *R.* 'Peachy Keen', unnamed seedling designated as R. WS 1, *R.* 'Gillian's Gold', *R.* 'Windsor Daybreak', *R.* 'Windsor Buttercup', *R.* 'Vivacious' and a fragrant *R.* 'Clear Yellow' which he's currently increasing. Dr. Gus Mehlquist showed slides of his rhododendron breeding research aimed at developing a white and a red rhododendron. Mr. Flemer finished the plant forum with slides of trumpet flowers *Campsis* × *tagliabuana* 'Mme. Galen' and *Campsis* 'Crimson Trumpet', a fragrant double flowered wisteria, a sugar maple, *Acer saccharum* 'Bonfire', *Aesculus pavia* 'Splendens', and two new cotoneasters bred at the U.S. National Arboretum for resistance to fire blight and apple scab.

Tuesday Evening, August 24, 1976

Dr. Chiko Haramaki served as moderator for the program on ericaceous plants.

DECIDUOUS AZALEA LINER PRODUCTION

WALTER F. GRAMPP

Lincroft, New Jersey

When we decided to go into azalea production the first thing we did was to acquire good stock plants. They were fairly large plants, 4 to 5 ft in height. These were planted in well-prepared beds and were heavily mulched with pine bark. They were then cut back hard and left alone for two growing season.

Immediately after flowering the plants were dead-headed which seems to hasten shoot development. When the new shoots were 4 to 6″ long and slightly firm, cuttings were made. Normally, this is from May 1 to June 15. We have both cut and stripped them and it doesn't seem to make any difference.

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However we did try to leave a stub to encourage future branching.

The cuttings are dipped into a solution of Vapor Guard, Sevin and Captan as described by Larry Carville when he spoke to us in Mobile in 1967. We use two pails, one for the dip and one to drain the cuttings, which are then packed into plastic bags for storage in a cooler. We feel it is good for them to be in the cooler for a day or more; they seem more crisp and turgid. Also, as we run into rainy days, we have work for the inside crew.

The cuttings are stripped, the buds pinched out and dipped into Hormodin 3, to which Benlate is added. With later cuttings or those that are hardened, a slight wound is made with the fingernail.

The prepared cuttings are stuck in flats containing a peat and perlite medium; 1 bale German peat to 3 bags of coarse perlite, to which 1 cup of granular Aqua-Gro is added. This is thoroughly mixed and put through a shredder.

The flats are placed under mist in a shade house. We start with 1 min every 6 min, utilizing two 30 sec bursts. The weather determines the number of hours of misting during the day, and the time of the burst is gradually lessened.

When rooted (6 to 8 weeks) the cuttings are potted and placed under lights. The potting mix consists of 1 bale of peat, 2 bags of perlite (4 cu ft) 3/4 oz of FTE, 1 lb of Osmocote and 1 cup of Aqua-Gro granular. As the flats are filled, the potted plants are drenched with a solution of 4 oz Truban, 6 oz Benlate and 2 cups Aqua-Gro/100 gal water. The cuttings remain under lights until sufficient top growth has started. The amount of top growth does not seem to be critical, but it is vital that there is some for, in many cases, well-rooted cuttings that go into dormancy without breaking, will not break come spring. The amount and kind of light we give is not sufficient for photosynthesis but just enough to break the photoperiod requirements.

When we feel we have enough growth the lights are turned off and the heat kept to a minimum of 35°F for the winter. We try to keep the houses as cool as possible by ventilating in the spring, but it is very hard to keep them cool once the days get longer. The plants are trimmed 2 or 3 times in April and early May to keep them from becoming too leggy. A couple of years ago we tried sticking some of the trimmings and much to our amazement they rooted well and we were then doing two batches a year.

One advantage of April cuttings is that they do not need supplemental lighting, as they are rooted by June and grow

naturally, thus saving energy. An interesting aspect of our April cuttings was that some cultivars that had low rooting percentages in May/June did very well while some cultivars that we never had trouble with did poorly in April.

All the azalea cuttings are potted since we are selling liners and it is easy to handle them this way, and we are planting by a machine. The machine consists of two Holland Peat Pot Planters, mounted offset on a tool bar. The boys drop the peat pots into the guides which are then picked up by the fingers of the machine and dropped into a furrow made by the shoes. Rows 1 and 3 are planted, then the tractor comes back over the bed and plants rows 2 and 4. The plants are then mulched and left for 2 seasons at which time we get a heavy 12″ to 15″ plant.

INTERNAL FLOODING OF RHODODENDRON LEAVES IN WINTER STORAGE[1]

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Abstract. Internal leaf flooding is caused by movement of excessive water into leaves by root pressure while transpiration is inhibited by high relative humidity. Experimental evidence indicated that neither the flooded condition, nor freezing alone cause leaf injury. Flooded leaves were somewhat less cold hardy than normal leaves. Holding at low temperatures for 20 hours or more caused much more injury to both normal and flooded leaves than freezing for 2 hours. Tests of leaves sampled in Febuary revealed a wide variation in cold hardiness among cultivars and among plants of the same cultivar in the field and in storage. Suggestions are given for clearing leaves of internal flooding and for preventing injury associated with flooding.

One of the major reasons for placing plants in winter storage is for protection from damage. Nurserymen are concerned when storage injury develops and demand an explanation and recommendations for avoiding it. Questions have arisen about a condition called internal leaf flooding that may occur on rhododendron in storage.

Normal leaves have air-filled intercellular spaces occupying perhaps 10 to 20% of the leaf. Flooded leaves have dark blotches due to water infiltration of the intercellular spaces. It is not surprising that the discovery of this condition on

[1] Paper No. 2057, Massachusetts Agricultural Experimental Station University of Massachusetts at Amherst. This research supported (in part) from Experiment Station Project No. 207.

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rhododendron in storage causes concern, because it is not seen in the field and it can be an indication of leaf injury. Our observations indicate that leaf flooding occurs rather commonly on certain cultivars in storage without being associated with any injury at all. In fact we believe that the condition may develop and disappear without being seen by the nurseryman.

CAUSE OF LEAF FLOODING

Internal leaf flooding is caused by a combination of two conditions: (a) practically 100% relative humidity and probably wet leaves, which prevent any loss of internal water from the leaves, and (b) water being forced into the leaves under pressure.

Winter storages for rhododendron are usually designed to provide high relative humidity, using polyethylene as a vapor barrier, in order to prevent leaf damage from desiccation, especially while root balls are frozen. Very high moisture conditions develop in these storages during periods of rainy weather. However, the process by which water is forced into the leaves is not as apparent. Under conditions of low transpiration, roots of plants may accumulate nutrient salts in the xylem to the point that the osmotic concentration in the root xylem is considerably higher than in the soil water. Water then moves into the root xylem by osmosis, developing a pressure approximately equal to the difference in the osmotic concentrations inside and outside the root. Since the xylem is more or less a continuous open system from roots to leaves, the pressure in the roots forces water up the stem and into the leaves. This "root pressure" has been measured to reach as high as 2 atmospheres, or about 29 p.s.i. Root pressure accounts for exudation of water droplets at night from some foliage plants and for "breeding" of grape vines and birches when cut in the spring before leaf expansion. Further information on root pressure in plants can be found in Kramer (1).

Some nurserymen believe that leaf flooding is associated with below-freezing temperatures. It seems certain that root pressure could not force water into the leaves while the soil is frozen, because ice could not move from the soil into the root, or up the stem to the leaf. Furthermore, it is unlikely that nutrient salts would be accumulated in the roots while soil and roots are frozen. It is possible that freezing and thawing could somehow stimulate the salt accumulation process, but to our knowledge this has not been investigated.

We have been asked whether a heavily fertilized rhododendron is more likely to develop leaf flooding than a lightly fertilized plant. There are reports in the literature (2) that high nit-

rogen fertilization increases root pressure in some plants, so by inference it might increase leaf flooding.

Leaf flooding does not occur in the field because transpirational loss of water from leaves prevents the "back-up" conditions required for flooding. Transpiration also keeps water moving through the xylem, sweeping salts out so that the concentration is too low for osmotic pressure to develop.

In summary, the sequence of events leading to internal leaf flooding in storage is (a) an extended period of high humidity while the soil ball is not frozen; (b) followed by a period of extremely high humidity and probably wet leaves; (c) salts accumulate in root xylem; (d) osmotic pressure forces water into the root xylem, through the stem to leaf cells and (e) when the leaf cells become fully turgid, root pressure forces water into spaces between cells that are normally filled with air.

INJURY FROM INTERNAL FLOODING

We have seen many cases of leaf flooding in storage without any resulting damage. The flooding disappears and leaves become normal in a few hours or days when the weather changes from rainy to dry and sunny so that water can evaporate from the leaves. Nurserymen have reported, however, that severe injury does occur, especially if the leaves freeze while flooded. Therefore, research was conducted to determine if flooded leaves were more sensitive to injury than normal leaves.

Three *Rhododendron* cultivars were studies: 'Nova Zembla', said to be the most frequently flooded, 'Mrs. P. den Ouden', also frequently flooded, and 'Roseum Elegans', never known to show flooding. Flooding was produced experimentally in leaves on 6 to 8-inch stems. The leaves were enclosed in a polyethylene bag and water forced in the cut end of the stem under 30 to 50 p.s.i. pressure. For freezing tests, leaves were removed and frozen at 5°F/hr in plastic tubes in a temperature-controlled liquid bath. They were thawed slowly and examined visually for injury after a few days at room temperature. Typically, the first indication of injury was browning of midribs and veins (rated as slight injury); lower temperatures produced black or brown areas. Browning or blackening of 75% of the leaf was rated as severe injury. Four to six leaves provided experimental replications.

In artificially flooding the leaves it was observed that 'Roseum Elegans' required more time at a given pressure than the other two cultivars (Table 1). This may have been due to slower movement of water through the stem caused by either smaller xylem tubes, or more obstacles, or both. The greater re-

sistance to water movement in the stem of 'Roseum Elegans' could account for the fact that leaf flooding is rarely seen in this cultivar, although it could occur if conditions for flooding persisted long enough.

Table 1. Time required to flood leaves of three rhododendron cultivars by forcing water through cut end of stems.

Cultivar	30 p.s.i.	50 p.s.i.
'Mrs. P. den Ouden'	10-15 min	5-10 min
'Nova Zembla'	15-20	10-15
'Roseum Elegans'	45	25-30

Six branches of each cultivar with flooded leaves were enclosed in polyethylene bags, with cut ends in water, and placed in dark storage just above freezing. After 6 weeks, the branches with still flooded leaves were removed from storage and exposed to room temperature. The flooding disappeared within 24 hours and no injury could be seen. These results confirm that internal leaf flooding alone is not especially harmful.

Since freezing has been suggested as a cause of injury to flooded leaves, tests were conducted on the relative cold hardiness of flooded and normal leaves. In the first tests, leaves were held frozen for 2 hours at test temperatures from 20° to -30°F (Table 2). Normal leaves of 'Nova Zembla' and 'Roseum Elegans' collected from the field were not injured. Flooded leaves were slightly to moderately injured by the lowest temperatures. Normal and flooded leaves of 'Mrs. P. den Ouden' from the storage were about equally injured by 10°F and lower temperatures. These results show that freezing alone does not necessarily damage flooded leaves, since flooded 'Nova Zembla' leaves were frozen at -10°F without injury. Likewise flooded 'Roseum Elegans' leaves were frozen at 0°F and 'Mrs. P. den Ouden' leaves were frozen to 20°F without injury. The results do suggest that flooded leaves are more sensitive than normal leaves to freezing injury. Apparently, however, the cold hardiness of flooded leaves is related to the cold hardiness of normal leaves of the same plant; i.e., when normal leaves are very hardy, flooded leaves are also quite hardy.

Table 2. Injury to rhododendron leaves from 2 hours at several freezing temperatures (°F).

Cultivar & Source	Condition	20°	10°	0°	-10°	-20°	-30°
'Nova Zembla'	Normal	0[1]	0	0	0	0	0
(field)	Flooded	0	0	0	0	+	+
'Roseum Elegans'	Normal	0	0	0	0	0	0
(field)	Flooded	0	0	0	+	++	++
'Mrs. P. den Ouden'	Normal	0	++	+++	+++	+++	+++
(dark barn storage)	Flooded	0	+++	+++	+++	+++	+++

[1] Injury sumbols: 0 no injury, + slight injury, ++ moderate injury, +++ severe injury.

Since leaves in storage may be frozen for several hours, a test was conducted in which normal and flooded leaves of the two hardier cultivars were held for 20 hours at three test temperatures; 0°, -10° and -20°F. The procedure used was such that leaves exposed to the two lower temperatures were also exposed to the higher temperatures, so that those held 20 hours at -10°F had also been held 20 hours at 0°F, and those held 20 hours at -20°F had been held 20 hours at both 0°F and -10°F. These long periods of freezing caused much more injury to leaves of the two hardy cultivars (Table 3), especially at -10°F and -20°F, than when the freezing time was only two hours (Table 2). Flooded leaves showed slight to moderate injury after 20 hours at 0°F, whereas normal leaves were uninjured (Table 3). Generally the differences in hardiness were not of great magnitude. In another test (data not shown) leaves were held frozen at 20°F for 9 days. Flooded leaves of 'Mrs. P. den Ouden' from dark storage were severely injured, but normal leaves were not injured. Leaves of 'Nova Zembla' from a poly house were uninjured, whether flooded or not.

Table 3. Injury to rhododendron leaves from being held 20 hours at 3 freezing temperatures (°F)[1].

Cultivar	Condition	0°	-10°	-20°
'Nova Zembla'	Normal	0[2]	+++	+++
(field)	Flooded	++	+++	+++
'Roseum Elegans'	Normal	0	+	+++
(field)	Flooded	+	++	+++

[1] Leaves exposed to -10°F were first exposed to 20 hours at 0°F; similarly, leaves exposed to -20°F were exposed to 20 hours at each of the 2 higher temperatures.

[2] Injury symbols: 0 no injury, + slight injury, ++ moderate injury, +++ severe injury.

The results of our freezing tests show that flooded leaves are less cold hardy than normal leaves, but they do not allow us to give a precise degree difference. Apparently the difference may vary with cultivar and with the hardiness of the normal leaves. A difference of about 10°F could be useful, although admittedly inaccurate, rule of thumb.

A previous test (Table 2) had compared leaf hardiness of two cultivars in the field and one cultivar from storage, the latter being much less hardy than those from the field. Since internal leaf flooding is a storage condition, it seemed desirable to compare the leaf hardiness of cultivars in storage. With the kind of permission of Weston Nurseries, we were able to collect samples of several cultivars from storage and field in February. The results of hardiness tests of three cultivars are shown in Table 4. A particularly interesting comparison for 'Nova Zembla' revealed that plants stored in the relatively warm barn (min

25°F) were less hardy than plants in the unheated poly house (min 10°F), and both were less hardy than plants in the field. Both 'Dr. H.C. Dresselhuys' and 'Mrs. P. den Ouden' were 15 to 20°F less hardy in barn storage than in the field, and 'Mrs. P. den Ouden' was markedly less hardy than either of the other cultivars. Since flooded leaves are perhaps 10°F less hardy than normal leaves, we might expect injury to flooded leaves in these dark storage if the storage air temperature were to fall briefly to 0°F for 'Nova Zembla', 10°F for 'Dr. H.C. Dresselhuys' and 20°F for 'Mrs. P. den Ouden'. Injury might occur at even higher temperatures if the cold lasted for several days.

Table 4. Hardiness of rhododendron leaves (not flooded) collected in February from field and storage.

Cultivar	Source	Estimated min. temp. (°F)	Date Collected	Damaging temp. (°F)[1]
'Nova Zembla'	Field	-10°	Feb. 6	*[2]
	Poly house	10°	Feb. 19	-20
	Dark barn	25°	Feb. 26	-10
'Dr. H.C. Dresselhuys'	Field	-10°	Feb. 26	-20
	Dark barn	25°	Feb. 26	0
'Mrs. P. den Ouden	Field	-10°	Feb. 26	-5
	Dark barn	25°	Feb. 26	10

[1] Leaves held 2 hours at test temperatures.
[2]* indicates not damaged at -20°F.

RECOMMENDATIONS

It may not be feasible or advisable to try to prevent internal leaf flooding in storage, since high humidity is needed to prevent leaf desiccation, especially while root balls are frozen. Leaves should be watched for flooding, especially after an extended period of rainy weather. Judicious ventilation for a day or two when the weather clears should cause the flooding to disappear. Ventilation should not be done when outside air is much below freezing, nor when root balls are frozen. If ventilation is not feasible, and leaves remain flooded, precautions should be made to prevent severe freezing, especially for several hours. Plants removed from storage in a flooded condition would be vulnerable to injury from a sharp freeze.

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CALLUNA AND ERICA PRODUCTION AND DISTRIBUTION

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Calluna and *Erica* present different ornamental qualities from most other plants with which we work. There are many species of *Erica*, only four of which are hardy in northern climates and one of these, *E. cinerea*, is marginal. *Calluna vulgaris*, typically called heather, has provided over 200 named cultivars in a variety of color, texture, and form not seen elsewhere in a single species. Those who took the Plant Propagator's trip to England in 1973 will well remember this diversity.

Within their relatively dwarf stature, growth habits vary from distinctly upright to completely prostrate. Flower colors include clear white, near reds, a clear pink and all shades of rose and lavender. Flowering time is unbelievably diverse. On Long Island we have blooms in the garden in every month of the year except May. Textures vary greatly but probably the most pronounced characteristic, particularly of *Calluna vulgaris* is its extremely wide range of foliage colors. They offer unlimited potential for creation of color contrasts in formal or informal arrangements.

PRODUCTION

The production, from propagation to the finished plant, presents no unusual or difficult problem. The plants take to any efficient and sanitary system of culture in the field, or preferably, in containers. If one observes a few key procedures which will be discussed, the quality and production time should be readily controllable — at least it is under the northeast conditions in the U.S.

PROPAGATION

Propagation is by cuttings, taken primarily from field plants any time that good viable wood is available. Under our particular schedule we stick cuttings from mid-October to early November. You can expect to obtain 90-100% rooting of *Calluna* with the exception of very few cultivars and 70-100% success with *Erica*. Soft wood cuttings of *Erica* taken earlier give better rooting. *Erica vagans*, in particular, will do appreciably better if taken while tips are still growing and soft.

One major problem can occur if cuttings of *Calluna* are taken well into the winter and the stock plants are in the open

field. The low humidity of clear, cold fronts dehydrates *Calluna* foliage when frost is below their shallow root zone and there is no snow cover. There may be difficulty in finding good cutting wood.

Generally rooting in the fall months varies between 10 and 25 days from the easiest to the most difficult cultivars. The cuttings should root well in most any clean, well drained medium. A mixture of peat and perlite is excellent as long as the peat is prevented from getting soggy. Both *Calluna* and *Erica* grow well in straight peat. Moreover, in this medium they separate with minimal disturbance for the initial transplanting.

Intermittent mist can be used but is not needed late in the year. Any of the more difficult to root cultivars which we stick in September are rooted under mist but not the vast majority stuck after mid-October.

Most any size cutting, including heavy main branches, will root but our experience has been that the smallest cutting which can be handled will produce a much more even quality of end product and the production time will be no longer, if as long, than with larger cuttings. Moreover, much less propagation space is required. A 2 ft flat will hold 300 cuttings with ease. The small side cuttings torn off with a small heal are fine as long as one does not get too far into the plant and take the weaker shoots hidden from the light. Generally, it is as well and sometimes better to take a tip cutting of the most recent growth 1″ to 2″ long and readily snipped off with a finger or thumbnail.

The preparation of the cutting is confined to stripping the needles from the lower half, which though not essential, does permit more ease in sticking and less disease potential. Also the small wounds created in the process of stripping the leaves seem to promote rooting. There is no need for a fresh cut on the base of the cutting.

Cuttings of *Calluna vulgaris* receive no hormone treatment and are simply washed in a solution with either Captan or Benlate. *Erica* cuttings receive a moderate hormone. We have found the commercial liquid mixture Dip N' Grow — diluted 1 to 10 effective with relative ease of uniform application.

GROWING ON — INSIDE

As soon as the cuttings are rooted and hardened off, the propagation flat is moved into a growing-on house. They transplant well when just barely rooted but, because they grow so well in the propagation flat and can be separated without any great setback, we use this crop as the "fudge factor" in our winter transplanting schedule. We transplant them in December or

January as time permits. This timing does not seem to be a significant factor in achieving the finished product on schedule.

The rooted cuttings with a nice root ball are planted into 3" peat pots in flats in a Cornell-type medium of half Canadian sphagnum and half coarse vermiculite, to which we add 2½ lb dolomite lime, 2½ lb gypsum, 2½ lb superphosphate, 2 tbsp iron and 6 lb of Acid Electra per cubic yard. At transplanting or before, the top of the cutting is cut in half to assure multiple basal bud breaks and a good quality plant.

The transplants are grown on in double layer plastic houses heated by hot air distributed by overhead vented poly tubes and with the circulation fan going continuously for inside air movement and good disease control. The heat comes on at 70°F daytime and about 65°F nighttime with fans bringing in outside air at 85°F. While in the growing house no additional nutrients are added.

All plants are pruned heavily again in March or April, then 1 to 2 weeks prior to transplanting outside.

No insecticide is used on *Calluna* under cover. With *Erica carnea* and *Daboecia* (related to *Erica*) one should watch for spider mites as the house heats up later in spring. We use one or two preventative sprays of Pentac. We do not find a need for fungicides on *Erica carnea* or *E. cinerea* but have a regular 3 to 4 week spray program on *Calluna* and *Erica tetralix* while in the heated house.

Benlate can be a great help in disease control of these plants but do not get carried away and use it where there is no need. After some years of using Benlate alone we have some cultivars which never gave us the least difficulty before showing serious branch diseases above the soil line. Manzate 200 has been very effective with these disease problems.

During their stay in the growing house of 6-7 months, the plants are maintained primarily by hand irrigation. Most cultivars of both *Calluna* and *Erica* do as well or better on an automated capillary watering system with little or no hand touch up irrigation. Hand irrigation is heavy and infrequent, starting with intervals of about every 2 weeks in January and every 8 to 10 days by April to every 4 to 5 days in June or early July when the pots are full of roots and the fan is running all day long. *Calluna* and *Erica* are used to take up any slack in our transplanting schedule. They seem to suffer the least loss of growth by holding them in a hot covered house until last.

GROWING ON — OUTSIDE

When the plants are transplated into 6" plastic containers outside (under 50% shade for the first 1-3 weeks) we use a U.C.

type mix of 50% Canadian sphagnum and 50% clean, local concrete sand with 2½ lb dolomitic lime, 2½ lb gypsum, 3 lb superphosphate, 1½ tbsp iron and 2 tbsp fritted trace elements per cubic yard. For nitrogen, we add a 6 gr Agriform tablet of 14-4-6 per plant at planting. We apply another 6 gr tablet in late July or early August, and another about the end of October. The latter application, made a few weeks before winter cover goes on, becomes at least partially absorbed by fall and covers the plants' need adequately well through the following spring season.

Outside irrigation is overhead with 1 inch of water added every 2 days during the warm part of the growing season and with water reaching each plant from all four directions.

The pesticide program outside is similar to that used under cover. For *Calluna* — no insecticides are used but either Benlate or Manzate 200 is applied once a month. This is one of the keys to consistent quality. A plant marred by disease will have trouble catching up. For *Erica carnea* — no preventative fungicide — but a miticide — is used on all stock plants and any plants grown on to larger size.

One more pruning is made on *Erica carnea* and its hybrids before the end of July. If later it would interfere with flower bud development. All other *Erica* and *Calluna*, except the very dwarf and tightly growing rockgarden forms, are pruned about the end of August or early September before growth stops completely. Those plants, perhaps 5%, set aside for fall sale are not pruned.

The plants are overwintered in quonset huts under a single layer of white polyethylene. Captan and/or Benlate with a good latex sticker are used for Botrytis control under this cover.

MERCHANDIZING

The typical retail sale is by impulse based on their eye appeal. Impulse sales are heavy from late March to early April when the *Erica carnea* are in full bloom and the many beautiful winter foliage colors of *Calluna* are available. Sales fall off sharply in May with no flowers showing and the new growth obscuring the foliage charm of individual cultivars. Sales build up again in the low traffic period of June to August as individual cultivars of *Calluna* come into their particular flowering primes. They slow down in late summer with few cultivars in bloom, then pick up again as foliage colors begin to show with the shortening days in October.

These plants sell themselves at retail. In order to have these plants in front of the ultimate consumer in the right quantities at the right time some special approach is required. There are

so many nice colors, shapes and forms, you cannot bide your time and expect your retailers to slowly learn them all. You have to help things along. We use a form of semi-consignment sale where the retailer designates a given amount of space which we keep stocked with plants much like the breadman. We bring in fresh goods — those coming into bloom and remove those flowered out and unsold about every 3-4 weeks. A label provides considerable information and we furnish a display sign which ties to the label and assists the customers in their selections by listing the principal characteristics of each cultivar.

We get paid, as with our normal sales arrangement, for the plants we deliver less a credit for all returns in good condition. At the season's close there is a final pick up and credit balance for all leftover plants.

Under this sales method, the retailer gains in several ways. He has less risk and need not take his normal full mark-up to obtain his typical return. He has a colorful display that brightens up his retail sales area when it most needs it. He has very productive use of his space. The large display gives the customer greater selection and sells many more plants particularly in the quiet periods of very early spring and mid-summer. On the other hand he is responsible for maintenance and, in the heat and drought of mid-summer when *Calluna* plants are in full growth and full bloom and using a maximum amount of water, irrigation cannot be managed carelessly or the plants are instantly in trouble to the retailer's loss.

From the grower's viewpoint, it is of great value in introducing and selling new and unknown products. A given retailer who sells 800 to 1000 *Calluna* and *Erica* plants from a grower-managed display over a full season would probably sell noticeably less than 200 under procedures where the grower waits for the retailer to order. The effect on retail sales of the eye-catching large display is readily observable by the rapidity of sales from a freshly stocked display versus the very few sales when it falls down to the last few scattered plants which might be all that is ordered on the retailers own initiative. The grower exercises full control over the time when specific cultivars are on display in the retail yard. Equally important is the entry for sales of other plants occasioned by the delivery to restock this display.

This approach has been successful for us and might well be considered, perhaps in modified forms, as appropriate and beneficial for a number of other plant groups.

MOUNTAIN LAUREL SELECTIONS AND METHODS OF PROPAGATING THEM

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Mountain laurel, *Kalmia latifolia*, is slow in growing from seed to flower and clonal propagation is difficult. As a consequence, demand for common mountain laurel exceeds supply and most of the special flower and foliage selections are either unavailable or expensive.

Selection and breeding studies in recent years have focused attention on the diverse kinds of mountain laurel. These include: red-budded, banded, pink, or white-flowered types; selections with petaled flowers, and some with willow-like leaves or miniature habit. The genetic diversity, clonal selections, culture, and propagation techniques were recently reviewed in a book (3). Laurel propagation has also been discussed by Jaynes (2), Eichelser (1), and Radder (4) in the Proceedings of the International Plant Propagators' Society.

Figure 1. A new seedling selection of the banded type, *K. latifolia* form *fuscata* where the purplish-cinnamon brown pigment virtually fills the inside of the corolla. Crosses were made in 1976 to produce seedlings that will have the same deep coloration on the corolla face and, in addition, red pigment on the bud and back side of the open flower.

Seed. Mountain laurel seed is small, about 1.4 million seeds to the ounce. It will germinate without any special pretreatment but the germination percentage of freshly-harvested seed can be enhanced about 50% by soaking for 12 to 24 hrs in

Figure 2. *Kalmia* 'Shooting Star', an unusual flower form of mountain laurel found in the wild in 1971 at Hanging Rock State Park, Danbury, North Carolina.

200 ppm gibberellin (GA). Seed stored more than 6 months requires no GA treatment for complete germination. The seed germinates best near 72°F; at 79° and 86° fewer seeds germinate and at 64°, although germination is good, seedling growth is slow.

Germination and seedling growth are greatly enhanced by enriching the air with CO_2 from the normal 300 ppm to 2,000, so long as light and other conditions are not limiting. Seedlings will sometimes stagnate, even under apparently good growing conditions, and form a "rosette". A foliar spray of 200 ppm GA is useful to stimulate such plants to elongate and resume growth.

Some selected mountain laurels can be reproduced true-to-type from seed. However, seed propagation of selections depends on knowledge of how the desirable traits are inherited. Red-budded, white-flowered, and miniature habit types are reproducible from seed if both pollen and seed parent are of the same type. Seed set from self-pollination is usually poor and plants grown from the seeds are often weak. Emasculation and hand pollination of flowers is tedious, but bumble bees can be "harnessed" to do the work. Parent plants with flower buds are planted together in the spring and before the flowers open the plants are covered with an insect-proof, screened cage. When the flowers open a bumble bee is placed in the cage. They are easy to catch in a jar when they are visiting a deep throated flower like weigela. The bee cross-pollinates the flowers and

the seed can be harvested in the fall. Banded laurel has not yet been produced completely true-to-type from seed, but 50% of the seedlings from a plant with banded flowers and pollinated by a normal mountain laurel will be banded.

Cuttings. Mountain laurel selections can be propagated from cuttings but are rarely propagated in this way commercially, indicating that there are problems. The best time of year to take cuttings is not agreed upon. My best success over the past several years has been with fall (early October) cuttings. Radder (4) had good success with July cuttings and Eichelsor (1) and others have had fair success for several years with December and January cuttings. A disadvantage with fall-rooted cuttings is the need for cold treatment of the rooted cuttings to obtain uniform flushing of new growth in the spring. Exposing the cuttings to long days with lights from the time of sticking is not enough. December-January cuttings have had enough cold to break dormancy after rooting. Rooting generally takes 3 to 5 months regardless of the time of year the cuttings are stuck.

The results of auxin treatments to stimulate rooting are mixed. Some clones respond to certain treatments whereas others consistently root without auxin or wounding. A few selected, relatively easy-to-root clones are listed in Table 1. *Kalmai latifolia* 'Pink Surprise' is a pink selection that roots with surprising ease. *K. latifolia* 'Ostbo Red' is propagated commercially from cuttings in the U.S. Northwest, but under our conditions is much more difficult to root than the other red-bud selections listed. Note that with these easy-to-root clones more than 50% of the cuttings root every year, whereas random selections average 10 to 40% rooting.

As more selections are tested for ease of rooting more will be found. Once good rooting clones are discovered cuttings should be taken from plants kept in the juvenile vegetative

Table 1. Rooting of fall cuttings of selected *Kalmia latifolia* clones in a humidity case; no auxin treatment. (Medium — 2 parts peat: 1 part perlite. Temperature — 70-80°F)

	Percent rooted[2]							
Selection[1]	1969	1970	1971	1972	1973	1974	1975	Average for all years
'Pink Surprise'	100	50	90	93	80	92	70	76
×120 plt 18		50	60	82	60	72	60	66
×120 plt 23		55	100	100	90	87	80	82
×122 plt 9		86	80	90	—	96	100	93
×122 plt 11		89	67	62	100	92	80	80
×122 plt 13		92	—	80	50	100	93	87
'Ostbo Red'		20	23	0	10	48	40	34

[1] All selections are red-buds except for 'Pink Surprise'
[2] Aver. of 20 cuttings of each clone were tested each year

phase. Cuttings from 1 to 2 year old seedlings, young grafts, and rooted cuttings still in the vegetative phase root much more readily than those taken from older plants.

Grafting. Selections difficult to obtain from seed and unresponsive in the cutting bench can be grafted. The technique is essentially the same as that used for other evergreens, especially rhododendrons. They can be side-grafted or cut back and splice or cleft-grafted. Grafts made in late winter force rapidly. Sprouting from the stock is seldom a problem after the first season's growth.

Most of the unique and desirable characteristics of the mountain laurel selections of today can be genetically transferred to a race of miniature mountain laurel. However, until we can do a better job of growing the "normal" forms our enthusiasm for slower growing miniatures will have to be tempered.

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Wednesday Morning Session, August 25, 1976

The Wednesday morning session convened at 8:35 a.m. with Mr. Allen Cook serving as moderator.

WHAT'S NEW IN POLY STRUCTURES

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Research on the engineering aspects of greenhouses at Rutgers has been primarily oriented to the development of structures which are functional, low cost and energy conserving. In the last few years energy conservation has been the highest priority goal and research has begun on alternative energy sources.

The crop requirements and the weather patterns at the greenhosue location are primary factors to be considered. The structure and its control systems must work together to provide the crop requirements under the prevailing weather conditions at a reasonable cost.

AN ENERGY-SAVING NATURALLY-VENTILATED PLASTIC GREENHOUSE

Natural ventilation obtained by openings in the ridge and side walls provides for movement of air from the greenhouse when the inside temperature is warmer than outside. One major drawback of natural ventilation is that on very warm, still days the temperatures inside and outside the greenhouses may be the same. Mechanical ventilation with controlled air flow and inlets can eliminate many problems occurring with natural ventilation but requires great investment and high operating costs.

The energy crisis has increased mechanical ventilation costs as well as heating costs. Polyethylene covered greenhouses rely almost entirely upon mechanical ventilation (6) and openings in the roof increase covering time. Removing plastic from the sides is effective only in small houses during spring and fall. In large houses located in areas of very little natural convection, little ventilation will occur through the sides.

The plastic-covered greenhouse described here is designed to overcome these problems and would be recommended for areas without severe snowfall or extremely low temperatures or for seasonal use in other areas.

Figure 1 shows a cross section of the building. Its monitor-roof design allows for natural ventilation to occur from the top of the greenhouse while still preserving the features of rapid covering required for plastic film structures. The vertical area which serves as the ventilation opening is closed by four vertically stacked inflated plastic 12″ diameter tubes. These tubes nest together to close the 40″ opening. When ventilation is required, they are deflated one at a time in sequence on temperature rise.

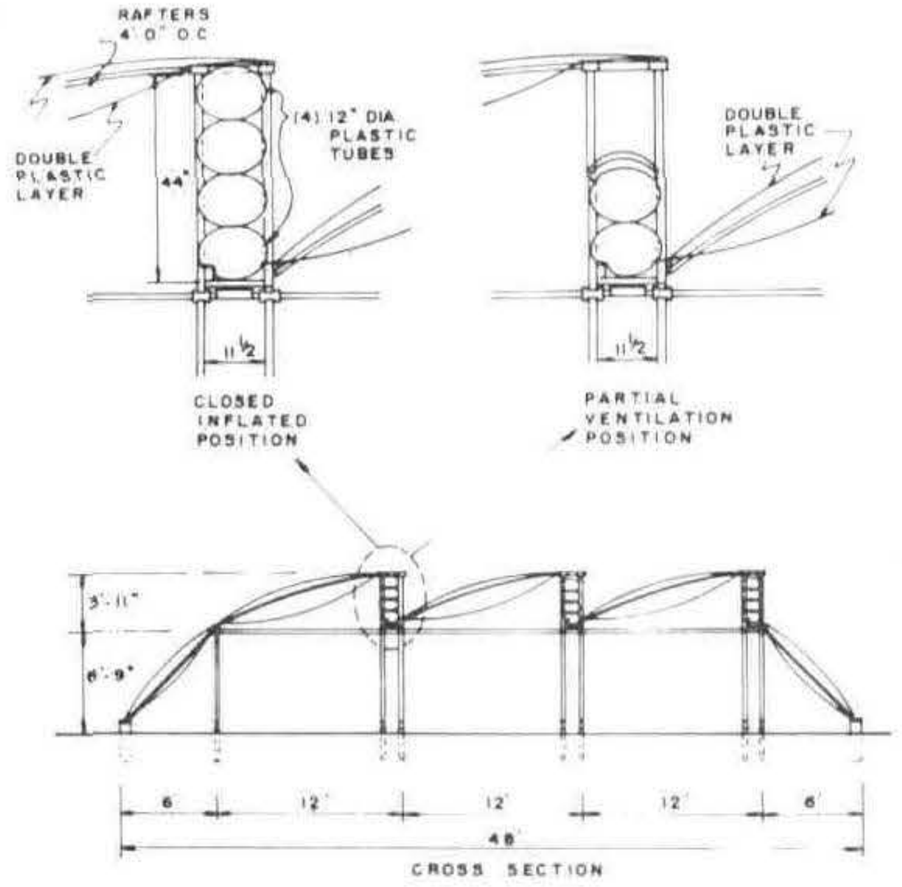

Figure 1. Monitor roof greenhouse.

The structure is designed in modules of 12 feet in both directions. Standard construction materials and standard widths of plastic film and tubing are used. It would normally be constructed 96 feet long and in widths needed by the grower. However, since fan ventilation is not needed, the length of the house can be predicated upon available lengths of plastic film or tubing, good crop management and materials handling practices, and not limitations of fan ventilation.

The entire greenhouse is covered with two layers of film which are separated by air pressure (8). Minimal wall structure is required and since there are no fans or louvers, the ends may be covered easily, quickly and inexpensively. It is structurally sound. Winds of 55 mph and gusts of up to 80 mph were recorded at a nearby weather station. The only damage occurred to the tubes which became twisted; damage by freezing could have taken place if freezing conditions had occurred during the storm. A recent modification in plastic tube selection should help eliminate this problem.

Normally the lowest of the four tubes is never deflated. This keeps the deflated plastic tubes in the gutter from obstructing the flow of water during rainstorms. As the thermostat calls for ventilation, the uppermost tube is deflated permitting natural ventilation to occur. If the temperature continues to in-

crease, successive thermostats deflate the tubes sequentially, increasing the ventilation rate. As temperatures fall, the process is reversed, and the opening is closed in sequence. The tubes are inflated or deflated by three small fans, each fan controlled by a thermostat.

The present tubes are constructed of two layers of 12-mil vinyl film electronically sealed to form 4 individual tubes when inflated. With this technique, all tubes are connected to each other and twisting is eliminated. The tubes are heavy enough to collapse by gravity eliminating the need for weights. Another advantage is that the tubes are physically attached, greatly reducing infiltration.

Summer temperatures have ranged between 5° to 10°F warmer inside the monitor house than outside. These temperatures were recorded without shading or crops growing inside. It was observed that opening the house between the sill and the soil line improved ventilation. Figure 2 illustrates a system which could be used to control a ground level inlet for the last stage of ventilation. This is when the inlet would be most helpful.

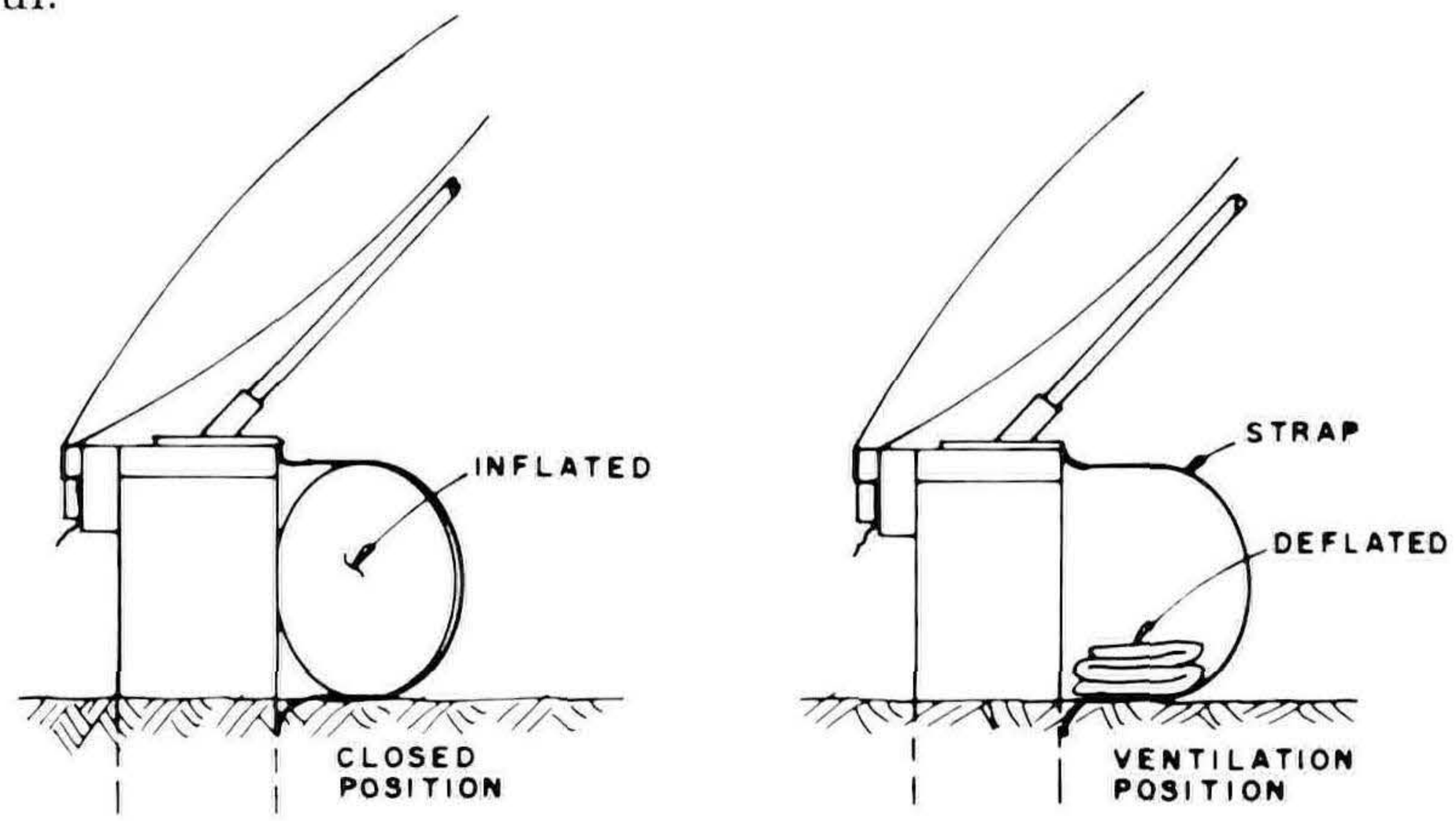

Figure 2. Ground level inlet.

No heating system has been installed in this greenhouse but probably any warm air system could be utilized. The nature of the structure causes shading from November through January. The greenhouse should be oriented with the gutter section running north-south for year-around operation so the shadow cast by the gutter and vertically stacked tubes would move from left of the gutter to the right of the gutter during the day. Locating this house in southern latitudes would alleviate this design problem.

The energy saving monitor roof plastic-covered greenhouse

performed well structurally and environmentally. Although control and precision of mechanical ventilation is relinquished (10), some applications with less than critical requirements may prove successful using these techniques. Initial investment will be less and operating costs greatly reduced.

A GREENHOUSE VENT CONTROLLER

Most polyethylene greenhouses are ventilated through exhaust fans mounted in one end wall with matching intake shutters at the opposite end. It is good practice to increase ventilation rates in stages with rising temperature to a maximum of about one air change per minute. One difficulty with this system is that at lower ventilation rates it is difficult to obtain satisfactory mixing of the cool incoming air with the greenhouse environment. The air enters through the inlet shutters at a low velocity and settles to the floor causing a localized cold spot. At full ventilation the inlet velocity is high enough to induce turbulent mixing and this problem does not occur.

A ventilation controller has been developed which will open a window in stages to match the amount of air being drawn in by the fans in up to four separate steps (10). At each stage the window opening is such that the entering air velocity is between 700 and 1000 fpm which induces air mixing. The construction and operation of the controller is described in detail by Roberts and Cheney (10). Variations of this unit have been installed for several years in commercial greenhouse situations and have been found to perform satisfactorily. Excellent control of ventilation is obtained at a relatively modest cost.

A CABLE SUPPORT POLYETHYLENE GREENHOUSE

To reduce the structural components in gutter-connected double-covered greenhouses, a cable design was built and tested (5,9). A cross section of the experimental house is shown in Figure 3. Available widths of film tubing, allowable stress in the film, design conditions and lumber standards indicate an optimum module or pole spacing of 12 feet in each direction.

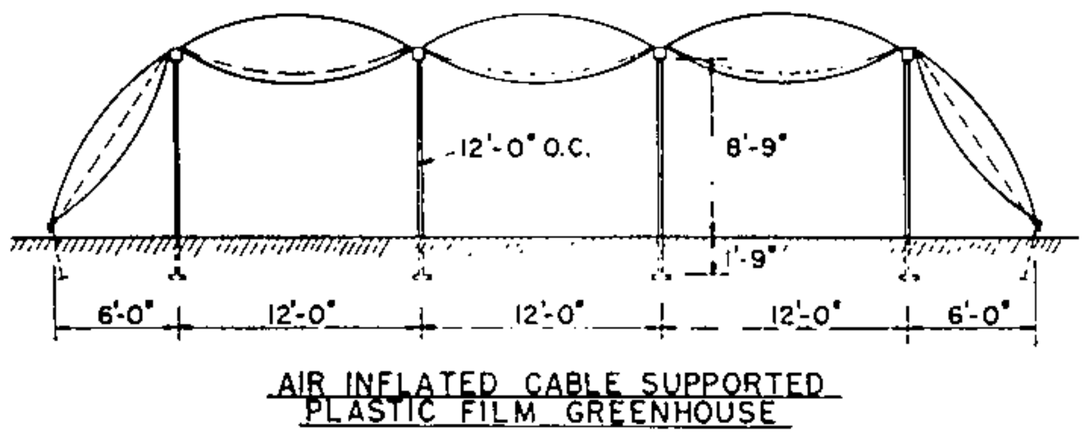

Figure 3. Cross section of 48′ × 48′ experimental greenhouse.

Various cross supports joining the gutters on 6 foot centers have been tried. These include nominal 5/16 inch nylon

covered cable, nominal 3/4 inch pipe, a special pipe/cable combination truss, 2 × 6 lumber and combinations of these components. The building in all of these designs has functioned well in wind, sustaining winds of 60 mph with no damage and very little deflection. One important structural observation of this type of structure is that classic methods of calculating wind loads are not appropriate. We believe this is because air-inflated structures are able to deflect under high winds and thereby relieve themselves of the greatest wind load effects.

Difficulties with this structure have been encountered in heavy snows as there is no means to support snow. If this structure is to be used under conditions of heavy snow load it will be necessary to make provisions to melt the snow off before excessive accumulation. The apparent advantages of this structure are:

1. Few structural components to cause shade within the greenhouse.
2. Simple erection techniques, modular construction and air-inflated design all reduce building costs.
3. Structural components of the greenhouse, posts and cables can provide support to vegetable crops which require it.
4. The double plastic cover can be easily and rapidly applied or removed without disturbing the crop.

ALTERNATIVE GREENHOUSE HEATING METHODS

Several years ago a number of ideas were proposed for heating greenhouses, assuming a large supply of warm water was available such as from the waste heat of an industrial operation (4). It was proposed that large heat transfer surfaces which could be unobtrusively incorporated in the structure at low cost were a necessary prerequisite to effective utilization of waste heat. One idea consisted of essentially floating a greenhouse on a pond of warm water if only a low cost floor could be found that would enable us to "walk on the water".

One practical solution to this problem has been developed using a porous concrete floor made with aggregate, cement and water but no sand. By adding an impermeable plastic layer and a gravel mass under the porous concrete a floor capable of storing warm water with a dry surface is created. A substantial amount of heat can be transferred from the warm floor to the greenhouse, but not enough to heat a polyethylene greenhouse in New Jersey in the coldest weather.

Double film polyethylene greenhouses require 30% less energy to heat than single glazed greenhouses of similar size. Ad-

ditional heat savings can be achieved by using horizontal and vertical curtains inside the greenhouse to reduce convection and radiation losses. Work at Rutgers in a glass greenhouse indicated a savings of over 50% when a black plastic curtain system, normally used for day length control, was used as a blanketing system. Simpkins et al (11) reported on various materials used for heat loss reduction in an environmental chamber and a prototype double-filmed greenhouse. Horizontal and vertical insulation curtains can significantly reduce energy losses in double-filmed greenhouses. Tests in a small greenhouse using a black polyethylene curtain indicate heat savings of 30% with an inside to outside temperature difference of 40°F and a 65% savings with a 10°F temperature difference. Reflective materials installed with the reflective side facing outward further increase the potential for savings.

Mechanical systems of all types are used to position or close the curtains during the night. The curtains, of course, must be stored in the daytime to minimize shading of the growing crops. Roberts (7) described a system which hangs the curtain from cables.

With the porous floor filled with warm water and the insulation curtain pulled, most of the heat is provided but on the coldest night more heat exchange capacity between the warm floor and the greenhouse air is required. A heat exchanger consisting of a sheet of plastic draped over a perforated pipe was developed. The pipe is attached to the insulation curtain-pulling cables so that it is elevated at night and drops to the floor in the daytime. At night, when extra heat is needed, warm water is pumped from storage under the floor through the perforated pipe. As it flows down in a sheet between the two layers of plastic, heat is given off to the greenhouse. At the bottom it runs through the porous concrete back to storage. The entire system is shown in cross section in Figure 4.

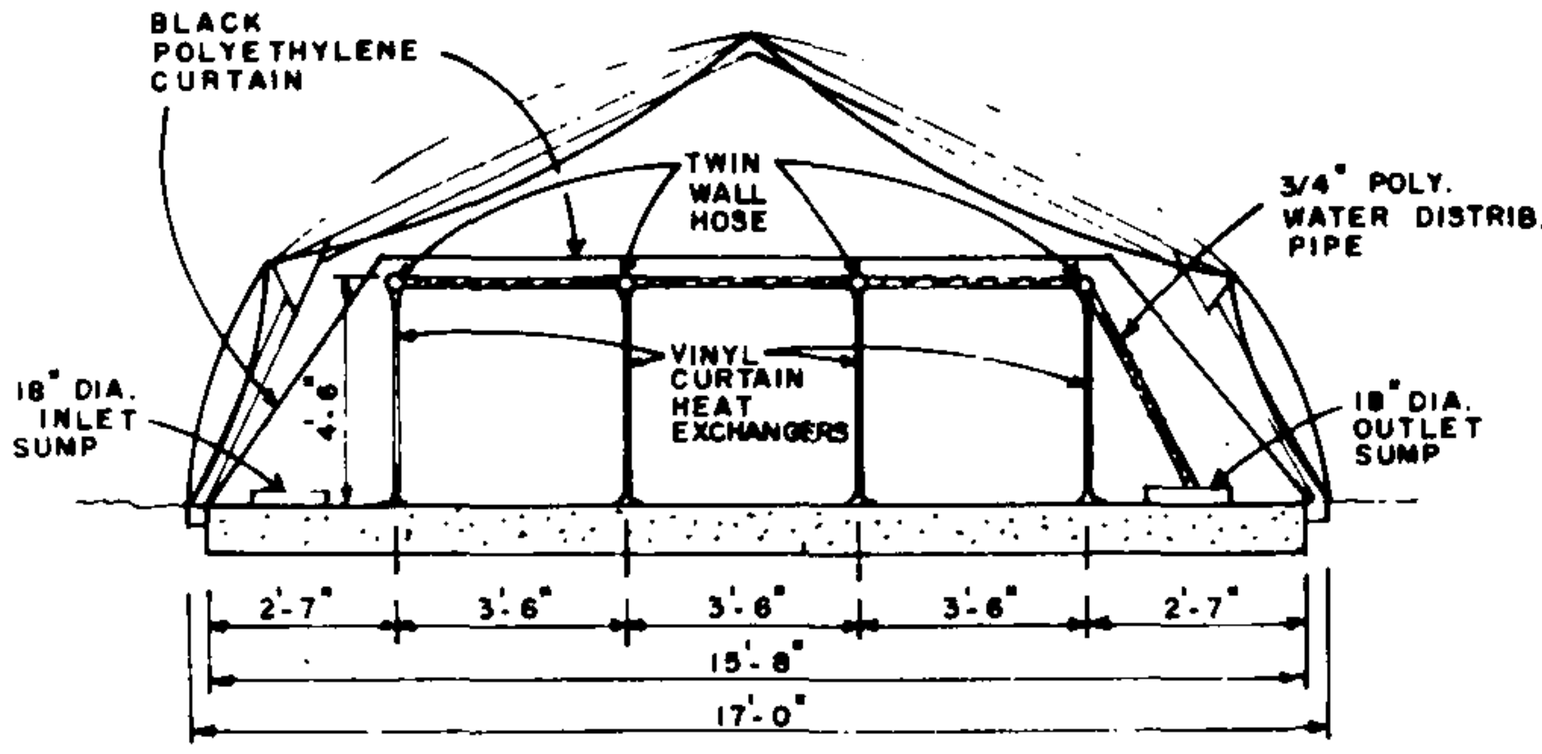

Figure 4. Double-layer air-inflated 17′ × 24′ polyethylene greenhouse with porous concrete floor, black polyethylene curtain and vinyl curtain heat exchangers.

One attractive source of warm water for the above system could be solar collectors. A simple solar collector is almost as efficient as more expensive units designed to deliver hot water (3). One style of collector that has been developed is shown in cross section in Figure 5.

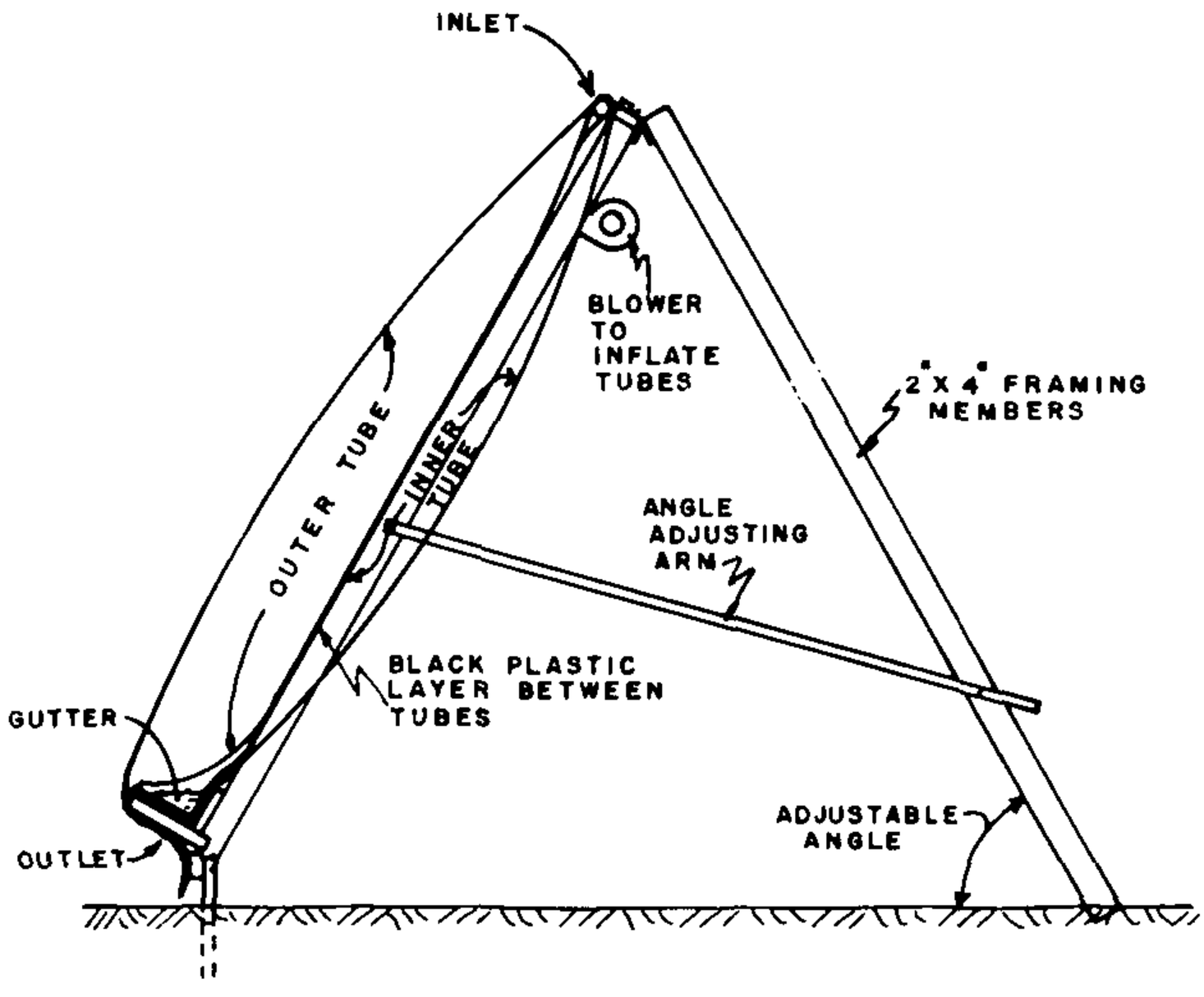

Figure 5. Cross section of sloped solar collector.

This collector is designed with a simple wooden frame that can have its angle from the horizontal adjusted. A single layer of black polyethylene film is sandwiched between two double layers of clear UV stabilized polyethylene. The two spaces between the clear pairs are inflated to provide structural stability and some insulation. Water is pumped through holes in a header pipe along the length of the unit at the top. The water trickles over the black plastic in sheet flow picking up heat from the sun and is collected in a gutter at the bottom from which it flows back to storage under the porous concrete by gravity. The sheeting action of the water at lower flow rates can be improved by adding detergent to the water or a scrim such as polypropylene shade netting over the black plastic layer.

Another idea developed for use where a completely paved floor is not wanted involves a heat exchanger/storage system. The heat exchanger should be part of the storage structure to minimize costs and equipment. The entire system must fit under the greenhouse benches and not interfere with normal operations. Most important, the materials must be low in cost. Long life and freedom from any maintenance are also desirable.

The basic components of this system are a plastic bag,

which runs underneath the bench for its entire length, and an insulated arch over this bag to provide an air plenum. A fan with thermostat control blows greenhouse air to be heated into the space between the arch and the water bag where it picks up heat, then leaves under a slot the length of the bottom of the arch. This system is shown in the drawing in Figure 6. The vertical posts would provide support for the benchtop. This unit has a large capacity for both heat storage and heat transfer when the fan is running. With the fan off there is relatively little heat transfer from the stored warm water.

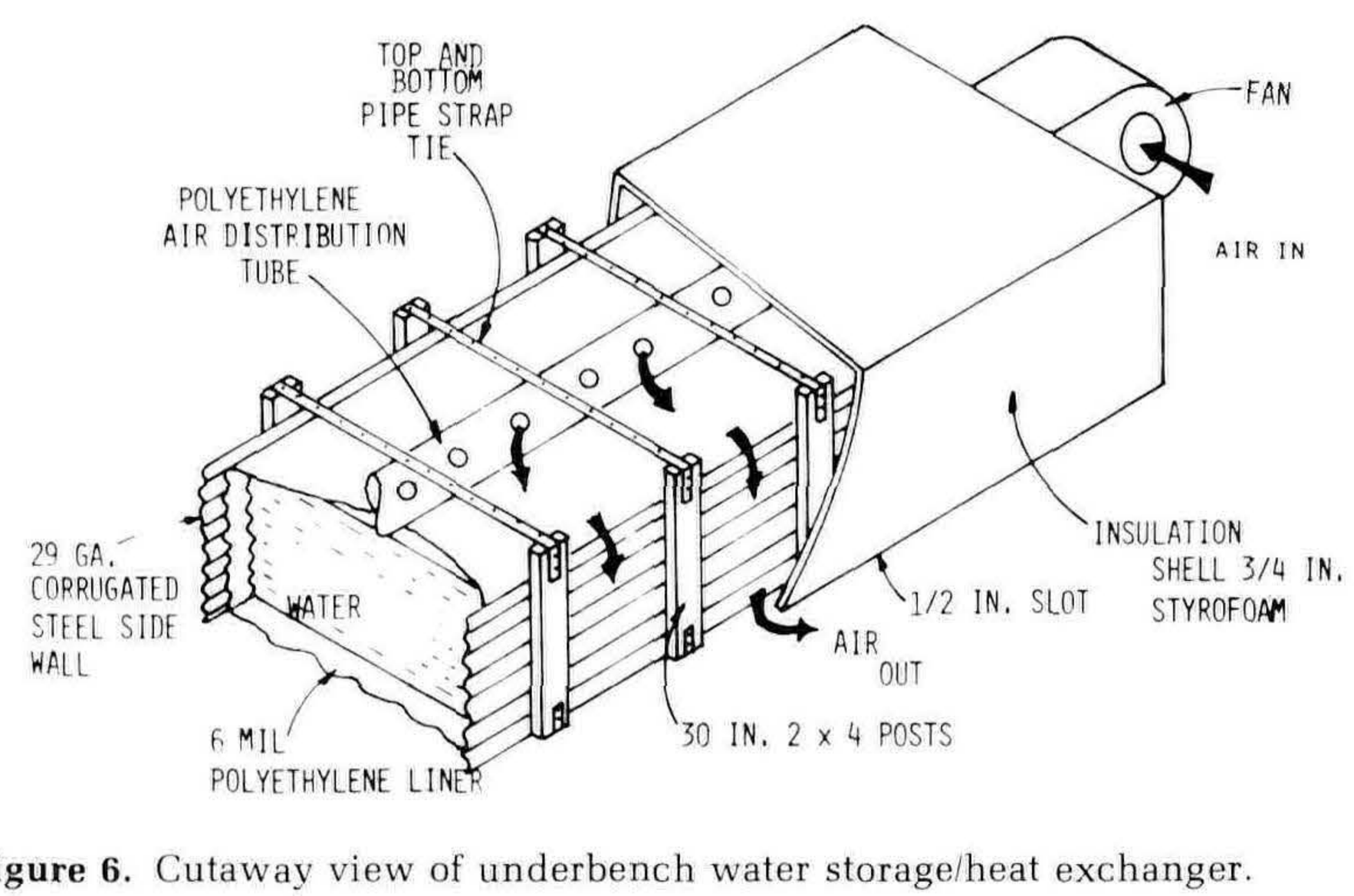

Figure 6. Cutaway view of underbench water storage/heat exchanger.

SUMMARY

Reduction of greenhouse heating and ventilating costs will continue to be important problems and imaginative solutions are needed. The most practical steps are in the area of heat conservation. Movable insulation curtains show great promise for heat conservation for any heat source.

Solar systems for greenhouse heating is dependent upon the development of equipment with much lower initial costs than the units now available and the use of energy conservation measures. The units discussed in this paper are by no means the only hope for effective, low-cost units, but do show promise. It is our feeling that if efficient heat exchangers that are capable of heating greenhouses with low-quality heat (warm water) can be developed, substantial reductions in heating costs will be possible. Also, it is important to get complete systems into operating greenhouses to begin to collect the experience that will let the "art" of solar design begin to develop.

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FREE HEAT OR DESIGNING FOR LOWER COST HEATING PROGRAMS

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My freshman economics teacher said, "There is no such thing as a free lunch." That also applies to the cost of heating propagation houses. My emphasis is: How can we decrease the cost of fossil fuel? Oil and gas and heat-making stoves were relatively cheap 10 years ago and we learned to enjoy their great convenience. Sometimes the cost was so low that we tried to heat up all outdoors. Some of you probably own a stainless steel infra-red heater that was advertised as keeping the frost off an acre of ground. But the cost of oil, gas, electricity, heaters and fin pipe have all gone up.

There are other heat sources that we ought to look into. One is earth heat — the heat in the soil — 6 — 10 — 100 ft deep. Heat pumps in our homes use earth heat. I believe that our poly sturctures should be designed as an "A" shape with perhaps a 30° rafter angle right down to the soil. You may not store many plants in that narrow angle, but your structure at night is picking up earth heat from that covered space. It also "slips" the wind better. So one of the changes that I suggest to combat cold weather is to change the shape of our buildings. I believe the day is gone when we build more hot bed sash. That was a small 2 ft high × 6 ft wide greenhouse. It is not very good for holding night heat. And besides, the labor stood outside in the sun, wind or snow.

In addition to earth heat, we ought to look at solar heat. Another change that some nurserymen are making is to move his business to the Sun Belt. TIME magazine says that is where many of your customers are migrating. If you are closer to the sun or at least in the South, you still have to learn how to use and conserve solar energy. Sun energy is radiant energy. We have to look at incoming radiation on a bright day and outgoing radiation all night long.

In our research in Georgia, we have been comparing different structures for several years. One thing I have observed is that a large cubic volume structure is beneficial. It encloses a large body of air which has some good temperature characteristics.

I know a man who built his poly houses with 6 ft gutter height. The next year he built another greenhouse with 8 ft gutter height (more headroom — more heat holding — more air

circulation). The next year he built 10 ft and the next year 13 ft gutter height. He could drive his van into the greenhouse to load it. On some hot days, even with exhaust fans, the hot air was several feet over the growing plants.

Let me tell you of my 2 × 4 model structure. Everyone will build a different design but I am not giving you a blueprint. I am looking at some heating characteristics.

In my model, there is a 20 ft post in the center and 40 ft rafters and several other posts on each side. That makes about a 30° roof angle with 70 ft of ground covered. I believe that is a good angle for snow, and it also slips wind which is a very common cause of greenhouse failure.

When I cover this frame with a single layer 4 mil clear poly, I record a high day heat and a relatively high heat loss at night. Remember, I am trying to decrease the fossil fuel oil bill. If I cover the frame with a double layer of poly, I can conserve a lot of night heat loss. Some of you have reported fuel savings of up to 30% from this simple step. In Georgia we have a lot of winter sunshine, so I spray the outside layer of film with white latex paint until a light meter tells me that 8000 ft-c at noon has been cut to 4000 ft-c. I add 50% shade to the poly cover. These two improvements over single poly are very inexpensive and they conserve a great deal of heat at night.

The next inexpensive step in utilizing solar heat has been called "fire water". Water has a high specific heat. It is slow to heat up during the day, thus tending to keep the greenhouse cooler at noon. It is slow to cool off at night, thus adding heat to the greenhouse air. In an effort to keep the cost down, we have not used big central storage tanks, coils and pumps. We have used common 50 gal drums. It is even better if they are painted black. They are big, cheap, long lasting, have a good amount of surface area for heat exchange and no moving parts. We place these barrels around the inside periphery of the greenhouse frame at about 6 ft centers. They are 12 inches below the sloped plastic roof and do not use up much floor space, The barrels are located at the coldest part of the structure. As the air at night cools, it migrates down the inside of the plastic ceiling and passes by the barrels of water which store the solar heat. The water warms the air as it flows by. With these simple heat conserving measures and no fossil fuel it is easy to maintain 33°F at plant height at 5 am when it is 15°F outside. When the water begins to freeze, the latent heat of fusion is released. In the process, it absorbs a lot of cold and gives off low-cost heat. On a night when it was -2.0°F outside, it was 25°F inside with ice forming in the barrels. With our zero fossil fuel program, we are not trying to keep 65°F inside. Many

woody plants and rooted cuttings will withstand air of 25° better than −2°F. This can turn a hard winter into a mild winter. Roots will grow.

I believe the system would work better if twice as many barrels are used. Consider that Cleveland, Rutgers and Long Island have relatively mild winter climates because of their proximity to large bodies of water. This year I intend to stack one barrel on another near the center of the house to increase the night heating ability.

Another heat saver is to line the inside of the north side of your greenhouse with some insulating material. I obtained some 1/2 inch styrofoam which is a very effective radiation barrier and placed it on the north side.

The last measure that I will suggest to lower the heat bill is to pull a black cloth at night. Mum growers have found that common black cloth or black plastic can make a 15°F difference — say between 50° and 35°F. I suggest it last because it is a relatively expensive installation, especially if it is time-clock operated. I believe at the present cost of fuel it may be cheaper to run the modine heater before you install an inside black plastic barrier for heat conservation at night. But when the price of fossil fuel goes up again you might consider pulling a black cover over your water barrels and over your crop every evening at 5 pm, especially on severe nights. This heat conserver could be removed at 9 am on a winter morning.

Horticultural technology is changing. I am convinced that these heat conservers will add a few pennies to your profit picture. What can you do? Double-layer poly, paint shading, water barrels, north side insulation, black cloth at night.

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A SOLAR POND FOR HEATING GREENHOUSES[1]

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Greenhouses are heated almost entirely by solar energy by day and fossil fuel by night. It is the fossil fuel requirement at night that is becoming or has become prohibitively costly. The greenhouse almost always accumulates surplus heat during daylight hours — even in Ohio mid-winters. A system that collects solar energy and stores greenhouse surplus heat for nighttime use could be very beneficial. Therefore, a solar pond is being studied as a solar collector and potential storage system along with the appropriate equipment to move heat to and from the greenhouse.

Natural solar ponds were first discovered in the early 1900's in Hungary (2). Temperatures up to 80°C (176°F) have been recorded. It is theorized that such ponds are fed by saltwater springs while fresh rainwater periodically flushes off the surface. The result is a stable pond of solar heated brine at the bottom of which is too dense to circulate to the surface and cool. More recently, researchers believe that a warm lake in Antarctica is a solar pond rather than a previously assumed hot spring lake (1). Tabor (5) has probably done some of the most extensive work to date to make the solar pond economically useful for power generation in Israel. Israel is in a high radiation area and the Dead Sea is a good brine source. Tabor was able to achieve small pond temperatures up to 90°C (194°F), but had numerous technical problems with large ponds. One large pond in a marsh area was destroyed by mud bulges and gas bubbles being generated as the pond warmed. A plastic liner was installed, but the same bubble action lifted the liner in various areas and caused severe mixing of the pond. There were also tedious problems in establishing the pond concentration

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A SOLAR POND FOR HEATING GREENHOUSES[1]

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Greenhouses are heated almost entirely by solar energy by day and fossil fuel by night. It is the fossil fuel requirement at night that is becoming or has become prohibitively costly. The greenhouse almost always accumulates surplus heat during daylight hours — even in Ohio mid-winters. A system that collects solar energy and stores greenhouse surplus heat for nighttime use could be very beneficial. Therefore, a solar pond is being studied as a solar collector and potential storage system along with the appropriate equipment to move heat to and from the greenhouse.

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gradients and the research was essentially stopped. Rabl and Nielsen (4) have studied the solar pond as a solution to space heating of residences in Ohio and similar areas. Rabl calculated that a pond equal in volume to a well insulated three bedroom home could meet all of the winter heat requirements of that home. Nielsen (3) further developed a unique salt gradient establishment procedure using a small pool and laboratory models.

Based on Rabl and Nielsen's work, a full-scale experimental solar pond was constructed adjacent to the Department of Agricultural Engineering greenhouse at the Ohio Agricultural Research and Development Center (OARDC). The pond was designed to meet all of the winter heat requirements of a 2000 ft^2 3 bedroom home or a 1000 ft^2 greenhouse in Wooster, Ohio.

DESIGN AND ESTABLISHMENT OF THE SOLAR POND

The OARDC pond is 12 ft deep, 28 ft wide and 60 ft long. The pond walls are post and plywood construction with a sand bottom. Two 30 mil chlorinated-polyethylene liners with a nylon scrim were fabricated to fit the pit and contain the brine. The side walls were insulated and the bottom is expected to become insulated as the warm pond dries out the surrounding soil.

The pond walls were designed to accommodate a standard clear span, pipe-frame plastic covered greenhouse. An air-inflated double plastic cover was installed over the pipe frame to: 1) help insulate the pond, 2) minimize dirt, trash and contamination, 3) quiet the surface to reduce light scatter and gradient mixing, and 4) raise the humidity above the water surface to control evaporation. A reflector was designed for the inside north greenhouse wall to increase the effective collection area of the pond.

A 6 ft convective zone of approximately 20% salt was established in the bottom half of the pond. The top half has a concentration gradient that varies from 20% at the depth to zero at the surface. No circulation occurs in the top since every layer is lighter than the layer beneath it.

The salt concentration gradient was established according to a technique developed by Nielsen (3). The pond was filled to

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[1] An excerpt from the proceedings of a workshop on "The Utilization of Solar Energy in Greenhouses and Integrated Greenhouse-Residential Systems", Braniff Place Hotel, Tucson, Arizona, April 4-6, 1976. Paper was approved for publication by the Ohio Agricultural Research and Development Center as Journal Series No. 79-87. This study was supported in part by the Energy Research and Development Administration and the USDA Agricultural Research Service (ERDA-ARS).

the three-quarter level with a 20% solution. Fresh water was carefully distributed over a floating sheet of plywood until the pond was full. The sizeable density difference of the freshwater and concentrated brine resulted in two distinct sections with little mixing. A pump with two inlets was then used to extract equal amounts of fluid from each section. The pump mixed the 20% solution with the freshwater to get a 10% solution. The 10% solution was injected between the original sections creating a new concentration zone occupying one-third of the top half of the pond. Subsequently, the three (0%, 10%, 20%) zones were used to form five zones (0%, 5%, 10%, 15%, and 20%) and the 5 zones were used to form nine final zones. The nine final zones were approximately 8 inches thick which was small enough for a perfect gradient to eventually form by diffusion and mixing.

RADIATION COLLECTION AND HEAT STORAGE

The solar pond is heated by solar radiation passing through the saltwater to the black liner holding the liquid. As the black liner temperature increases, heat is transferred to the 20% brine in the bottom half of the pond. The heated 20% brine rises no higher than the bottom layer of the gradient and cooler 20% brine moves down to replace it. The upper non-convective region is nearly transparent to incoming ultra-violet and visible radiation and nearly opaque to incoming infra-red and outgoing long-wave re-radiation. One meter of non-convective water is a good insulator with a conductivity equivalent to approximately 6 cm of styrofoam. Since the walls are also insulated, losses are reduced significantly.

A major advantage of the solar pond is that both summer and winter radiation can be collected and stored for later use. After a full summer's radiation, the pond temperature throughout the bottom half should approach boiling. The OARDC pond will be limited to 80°C (180°F) however, to maintain liner stability. This upper temperature limit will be controlled with discharge heat exchangers or by covering the pond with an opaque plastic film.

RESULTS

The gradient has required little maintenance since establishment. Salt diffuses very slowly fromt he more concetrated brine at the bottom to the less concentrated brine at the top. Brine was flushed off the surface and freshwater added two times during the fall of 1975, but mixing from the wind did not make the process seem very successful. Brine flushing was not attempted after the pond was covered and protected with a greenhouse. It is anticipated that flushing might not be necessary if a closed cycle system can be developed.

The maximum temperature for the first year was 45.5°C (114°F) on September 16, 1975. This maximum was far below the desired 82°C (180°F), since 1) the pond was not established until late summer and 2) nearly half of the first year absorbed heat was expected to be lost in drying out the soil under and around the pond. The changes in maximum pond temperature did not fluctuate as much as the radiation or outside air temperatures.

There are still numerous questions to be answered concerning the feasibility of the solar pond for space heating. The first real test of heat extraction is planned for the winter of 1976-77. Pond stability at high temperatures will be tested and evaluated. Solar ponds must be leakproof or be constructed to handle leaks that may occur at any time. Any leaks result in the pond losing both hot brine and dry soil insulation. Likewise, leaking brine may seriously contaminate surrounding water sources and soils. Currently, almost all ponds or pools leak or can be expected to leak at some time. There are no consistently effective ways of identifying and patching brine source leaks without draining the pond. Such problems however, may be solved with new liner technology.

Other problems observed in constructing and operating open ponds are: 1) wind will cause surface mixing, 2) rain water must be removed after storms and water must be added to make up evaporative losses, and 3) organic debris such as leaves will get blown into the pond. Leaves are buoyant at approximately 30 inches below the surface. These leaves can interfere with light transmission for 3 to 4 months before sinking to the bottom.

Much more is yet to be learned about solar ponds. The potential is exciting — the unanticipated problems are frustrating and often costly. The net result will hopefully be an acceptable and economical solution to the utilization of solar energy for space heating greenhouses and rural residences.

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BENCH GRAFTING PLUM AND APRICOT AS COMPARED TO T-BUDDING

BEN DAVIS II

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For many years we have been producing apricot, fruiting plum, and ornamental plum by T-budding on peach seedling rootstock. At no time have we been satisfied with the results. We have also tried T-budding on various plum rootstocks, mainly *Prunus americana,* with even worse results. About 2 years ago we had a block of *Prunus americana* on which the bud stand was so bad that we decided to graft them in the spring where they stood in the field. This was highly successful but also expensive. This success caused us to wonder if bench grafting might be a more economical way to produce these trees.

In January, 1975, we bench-grafted 7,169 apricot and plum scions on *Prunus americana* rootstock. The scions were dormant, one year growth. The grafting method used was whip and tongue, made at the crown of each seedling rootstock. The graft unions were wrapped with standard cloth grafting tape. The grafts were callused in the greenhouse for 10 days at about 65°F. After the callusing period the grafts were held in cold storage at 35° to 40°F until the proper planting time. They were planted in the spring at the same time as our normal planting time for apple grafts. We prefer to plant all bench grafts 5 to 10 days before peach blossoms are in full bloom. This timing will vary a little from season to season, but has proven to give best results.

In the fall, 1975, a count was made to determine the results of our grafting. There were a total of 3,067 salable trees produced from the 7,169 grafts, which figures out to 42.7%. All of the apricot and fruiting plum reached a caliper of 7/16″ or better and were dug and sold during the 1975-76 season. The ornamental plum grew more slowly and was carried over for digging in the fall of 1976. The figure of 42.7% salable trees from grafting compares with a 5 year average of 24.7% salable trees from T-budding. In addition, the majority of the grafted trees were big enough for sale in 1 year instead of two as required for T-budding.

The results with *Prunus salicina* 'Santa Rosa', our most popular selling plum cultivar, were even more outstanding. Over a 5 year period T-budding yielded an average of 13.5% salable trees. The best of the 5 years yielded only 24.6% salable trees. The 'Santa Rosa' bench grafts produced 62.6% salable

trees. Not only were the grafted trees produced in 1 year less time, they were healthier, better quality trees.

In January, 1976, we bench-grafted 35,626 apricot and plum. The same methods were used as previously described, except that after grafting, the scion of each graft was dipped in rose wax to prevent dehydration of the scion after planting. This had been somewhat of a problem on the previous year's grafts, especially on the apricots. The scions were dipped in the wax down to, but not including the taped graft union. The temperature of the wax was carefully controlled so as not to injure the scions. At planting time in the spring the grafts looked beautiful as they were unpacked from the boxes. In fact, they were some of the best looking grafts we have ever produced.

Now for the bad news. After planting, the grafts were treated with an 18″ band of Treflan herbicide at double the normal rate for our soil type. This rate has been recommended by the manufacturer for about 2 years as a means of controlling Johnson grass in soybean fields. (It also does a pretty good job controlling plum grafts). Nearly all of the grafts started to grow normally, and it looked as though we might get a 95% stand. However, when the new growth was 4 to 6 inches long, many of the grafts wilted and eventually died. The grafts that survived were mostly stunted and will have to be grown on for another year before being big enough to sell.

Even with the bad stand caused by the herbicide, the grafts still out-performed our average results for T-budding. At the time this paper was prepared, there were 13,720 live grafts of the original 35,626 planted, for a stand of 38.5%. Table 1 gives a comparison between T-budding and grafting.

In summary, we believe that bench grafting of apricot and plum is a successful method for making a significant reduction of production costs for these items.

Table 1. A comparison, by cultivar, between T-budding and grafting. The figures below represent the percentage of trees produced from each method of propagation.

Cultivar	T-Buds[1]	1975 Grafts[2]	1976 Grafts[3]
Apricots			
Prunus armeniaca 'Early Golden'	26.8%	26.5%	39.3%
Prunus armeniaca 'Moorpark'	33.8%	23.0%	31.5%
Plums			
(Prunus salicina × *P. angustifolia)* × *(P. salicina* × *P. munsoniana)* 'Bruce'	31.7%	56.3%	32.9%
Prunus insititia 'Burbank'	27.6%	50.6%	21.4%
Prunus insititia, damson plum	16.2%	35.8%	56.1%
Prunus (P. munsoniana ×*P. salicina)* × 'Golden'? 'Gold'	27.7%	38.8%	44.8%
Prunus nigra 'Hanska'	34.5%	56.1%	48.2%
Prunus salicina 'Methley'	—	—	17.9%

Table 1. (Continued)

Prunus salicina 'Ozark Premier'	30.1%	37.5%	24.5%
Prunus salicina 'Santa Rosa'	13.5%	62.6%	52.8%
(Prunus besseni × *P. salicina)* 'Sapa'	39.4%	—	59.7%
Prunus cerasifera "Allred'	13.5%	—	50.0%
(Prunus cerasifera 'Atropurpurea' × *P. salicina)* 'Hollywood'	—	—	77.0%
Prunus cerasifera 'Krauter Vesuvius'	15.4%	49.7%	30.7%
Prunus cerasifera 'Thundercloud'	19.3%	19.7%	29.9%
Average - All Cultivars	24.7%	42.7%	38.5%

[1] Five year average figures of salable trees.
[2] Salable trees produced from grafting.
[3] Live trees produced from grafting. Since herbicide stunted the trees, none will reach salable size the first year.

DEFOLIATION OF NURSERY STOCK FOR EARLY HARVEST[1]

STEVEN M. STILL

Kansas State University
Manhattan, Kansas

This paper combines information compiled from the extensive research of Dr. Fenton Larsen of Washington State University, my own recent defoliation study, and a recent survey of nurserymen concerned with the problems and present uses of defoliants.

Late leaf retention has plagued the nursery industry since storage of fall-dug stock began. This problem results in delayed digging and increased labor to hand-strip or "sweat" the leaves off. Heating of foliage in storage causes stem and bud damage and a possible increase in storage molds which can cause losses.

Leaves can be removed by mechanical or chemical means. The most common mechanical methods are hand-stripping and sweating in pits, both of which are expensive. This paper will discuss chemical defoliation.

A good chemical defoliant requires the following: at least 50% defoliation in a short time (2-3 weeks); inexpensive and easy application; and, most important to the nurseryman, not be injurious to treated plants. However, use of defoliants is often limited due to the danger of bud or bark damage and poor growth after transplanting.

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[1] Contribution No. 584-a, Department of Horticulture and Forestry, Kansas Agricultural Experiment Station, Manhattan, KS 66502.

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REVIEW OF LITERATURE

Present-day research was initiated by Milbrath *et al.* (10) who constructed chambers in 1937 containing ethylene gas to remove rose leaves. This proved effective within limitations due to the exacting procedures necessary in using ethylene. Later researchers (1,11,12) used Nacconol NR, copper sulfate, and endothal with varying results. Although none of these chemicals is used commercially today, research with them revealed that artificial leaf abscission is affected by concentration and time of application, environmental conditions, cultivar, age, and maturity of the plant. These factors are still of major concern.

In 1963, Dr. Larsen initiated research to find a suitable defoliant. His research through the years has seen the addition and deletion of several "promising" defoliants. The first favorable defoliant was potassium iodide (KI) (2) which is still used on a limited basis by rose growers. Bromodine (a bromine-iodine complex) (4), presently used on cherry and pear, surpassed KI in effectiveness. Larsen recently found that ethephon (Ethrel) and Dupont-WK (a surfactant) provide the best defoliation and least damage (5,6,7,8). Ethephon and D-WK can be used separately with good results or in combination which permits the use of lesser quantities of ethephon. Dupont-WK is slower acting but much safer than ethephon. Several nurserymen prefer it to the combination treatment, ethephon plus D-WK.

Larsen's studies on cycloheximide varied in results (9). Very low concentrations (25-50 ppm) cause rapid and complete defoliation but can be toxic, particularly to pear. Cycloheximide is not now used in commercial nursery practice. More recent research (13, 14) combined ethephon and endothall to provide a synergistic effect. Using the two materials together reduces the concentration of each. These two research efforts prompted our research at Kansas State University, Manhattan.

METHODS AND RESULTS

In October, 1975 we treated 5 species with various combinations of ethephon, endothall, and cycloheximide. Ethephon was applied at 250, 500, 1000, and 1500 ppm; endothall at 0, 250, 500, and 1000 ppm; and cycloheximide at 0, 5, and 10 ppm. The plants treated were 2-year grafts of *Malus* 'Golden Delicious', *Malus* 'Winesap', (*Malus pumila* 'Niedzwetzkyana' × *M. baccata)* 'Hopa' and 1-year seedings of *Malus* and *Pyrus*. Single applications were applied October 1, 1975. Sprays were applied to runoff with hand sprayers. Defoliation and damage was calculated after 2 weeks. The pear and apple seedlings were dug and stored, but the other species remained in the

field. Winter damage for all species was determined in the spring.

Results were encouraging during the fall with excellent defoliation and little terminal damage. The following lower rates were particularly effective: 250 ethephon, 250 endothall, and 10 ppm cycloheximide or 250 ethephon, 500 endothall, and 5 or 10 ppm cycloheximide. Defoliation was not so complete without endothall, even at higher rates of ethephon. Sterrett, *et al.* (13) also observed this synergistic effect between ethephon and endothall. Larsen (7) found that low rates of ethephon were relatively ineffective. Because of this, ethephon and endothall should be combined when lower rates (250 and 500 ppm) are used. These rates, however, are experimental and should not be interpreted as recommendations until further testing can be established.

Damage, as determined in the spring, was heavy. 'Golden Delicious' and 'Winesap' apple and pear seedlings were heavily damaged. The fall of 1975 was unseasonably warm, especially in October, and the 2-year stock in the field broke bud after defoliation. Much less bud-break occurred in 'Hopa' crabapple, which may explain the lesser damage in this species. Several nurserymen also reported that bud-break often occurs unless the nursery plants are dug immediately after defoliation. Additional research is necessary to determine whether the problem is chemical or environmental.

NURSERY SURVEY

The results from the questionnaire sent to nurserymen proved enlightening. Nurserymen experienced similar leaf retention problems with delayed digging. Species most often listed as retaining their leaves are presented in Table 1 and are not restricted to *Malus* and *Prunus*. Nurserymen who responded were interested in a good defoliant, but only about 12% presently are using one successfully. The chemicals most often mentioned were Bromodine, ethephon, and D-WK. The nurseries using chemical defoliants were generally from the Washington State area and had worked with Dr. Larsen. The midwestern and eastern nurseries, with a few exceptions, did not use defoliants.

FUTURE USE

The surveys indicate a ready market for a good chemical defoliant. It is doubtful if a given chemical can be found, except for naturally occurring ones like ABA, which would suffice for a large number of plants. Stone fruits, such as cherries and certain apple cultivars, respond best when defoliants are applied.

Apricot, peach, and pear are easily damaged. A nursery specializing in several large selling items should be able to adapt a safe concentration. Additional research is needed to determine when a plant is dormant to effectively defoliate it. This problem relates to the factors affecting abscission: temperature, humidity, precipitation, moisture, nutrition, species, cultivar, plant age, maturity, timing and concentration of application. Chemical defoliants are similar to herbicides in that mixing and timing of application are very important. Experimental defoliants should be used as cautiously as untested herbicides.

Table 1. List of genera and species having late leaf retention[1]

Acer spp.	*Prunus armeniaca*
Berberis spp.	*Prunus avium*
Betula spp.	*Prunus cerasus*
Castanea mollissima	*Prunus domestica*
Cornus florida	*Prunus mahaleb*
Cotinus spp.	*Prunus persica*
Crataegus spp.	*Pyrus* spp.
Forsythia spp.	*Quercus* spp.
Ligustrum spp.	*Rhamnus cathartica*
Malus spp.	*Rhamnus frangula* 'Columnaris'
Potentilla fruticosa	*Spiraea* spp.
Prunus americana	*Tilia* spp.

[1] This list, obtained from a survey of nurserymen in 1976, includes only those plants listed most often.

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LILAC PROPAGATION

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We have been propagating lilacs extensively since 1967 and due to the generosity of botanical gardens, arboreta, and park areas supplying propagating material, we now have one of the largest collections in the world and are the official registration authority for the International Lilac Society for lilac cultivars. We are aiming for a complete collection and any new additions would be most welcome. Stocking the collection to where it is today gave me the opportunity to try a great many species and cultivars. I have found lilacs to be consistent performers as far as rooting is concerned, the overall average of rooting during those years being 75-100%.

Timing. I have taken lilac cuttings from early June after flowering until July 26th in quantity, and have found even at this late date 70% rooting was obtained. In most cases we prefer to take our cuttings from the last week in June until the second week in July. Cuttings with mature leaves are much easier to handle. We have had mature-leaved cuttings in plastic bags in cool storage for a week and ended up with 80% rooting.

Media for Rooting. We have used sand, peat, and perlite in various combinations over the years and we find three parts sand to one part peat moss, preferably sphagnum peat, will give us the most consistent results. All cuttings are rooted in boxes for easy handling.

Systems and Method. We use an intermittent mist system with 550-A Florida nozzles overhead in a shaded, double-lined fibreglass greenhouse. The water supply is a well having very

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We have been propagating lilacs extensively since 1967 and due to the generosity of botanical gardens, arboreta, and park areas supplying propagating material, we now have one of the largest collections in the world and are the official registration authority for the International Lilac Society for lilac cultivars. We are aiming for a complete collection and any new additions would be most welcome. Stocking the collection to where it is today gave me the opportunity to try a great many species and cultivars. I have found lilacs to be consistent performers as far as rooting is concerned, the overall average of rooting during those years being 75-100%.

Timing. I have taken lilac cuttings from early June after flowering until July 26th in quantity, and have found even at this late date 70% rooting was obtained. In most cases we prefer to take our cuttings from the last week in June until the second week in July. Cuttings with mature leaves are much easier to handle. We have had mature-leaved cuttings in plastic bags in cool storage for a week and ended up with 80% rooting.

Media for Rooting. We have used sand, peat, and perlite in various combinations over the years and we find three parts sand to one part peat moss, preferably sphagnum peat, will give us the most consistent results. All cuttings are rooted in boxes for easy handling.

Systems and Method. We use an intermittent mist system with 550-A Florida nozzles overhead in a shaded, double-lined fibreglass greenhouse. The water supply is a well having very

hard water. The pressure is maintained about 60 p.s.i. The timing on the mist system has been controlled until this year by an electronic leaf made from bees wings, but now is on a 30-minute timer set to give a 30-second burst every 30 minutes. This is increased or decreased the first few weeks according to the weather. It comes on at 8:00 a.m. and shuts off at 7:00 p.m.

The mistbed has a heating cable set at 70°F which is activated during the cooler weather and this is an effective root-inducer. Suspended above the mistbed is a row of 100 watt electric light bulbs, 3 feet apart, which are timed to come on at 4:00 p.m. and shut off at 5:00 a.m. the following morning, thus keeping the cuttings on a long day and in a vegetative state. The lights also provide some heat on cold evenings and the foliage on the cuttings dries off during the light period. A ventilating fan set at 90°F keeps the air circulating and the temperature below 100°F.

Length of Cuttings and Treatment. Cuttings vary in length from 6-10 inches and vegetative shoots are preferred rather than shoots with flower buds. They are taken preferably in early morning and stuck as soon as possible. If this is not possible then cuttings are dipped in a pail of water and excess water removed by shaking. They are placed in plastic bags filled with air and stored in a cool place until ready for sticking. Wounding in a couple of places on the lower part of the cuttings is a part of the procedure and has proved to be an aid to a better root system. Various hormones at different strengths have been tried, but I now use equal parts of 1% IBA and Captan 50 W as a dry dip.

The cuttings are gradually hardened off in September and stored in the boxes until spring planting or when needed for winter grafting. A shaded cold frame in a lath-house gives us adequate protection during an average winter; when extreme conditions occur bottom heat is added.

Winter Propagation. Soft shoots from forced plants can be readily rooted under plastic in a greenhouse or under artificial lights.

We have available on request propagating material of most cultivars in our collection.

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COMPOSTED BARK MEDIA FOR CONTROL OF SOIL-BORNE PLANT PATHOGENS[1]

H.A.J. HOITINK AND H.A. POOLE[2]

During the last decade composted hardwood tree bark has partially or completely replaced peat in nursery potting media in the Midwest. One striking effect of this change has been the disappearance of various types of root diseases. With ericaceous plants, which are very susceptible to *Phytophthora* and *Pythium* root rots, significant increases in growth have been obtained in mixes consisting largely of composted bark rather than peat. Recently, research at the Ohio Agricultural Research and Development Center has focused on the basic mechanisms underlying this suppression of root diseases. It has been found that composting, with frequent turning of stacks (once every 2 weeks), eradicates plant pathogens. The temperature of compost stacks reaches 120° to 160°F for a period of 6 to 12 weeks, depending on the type of bark being composted. Pine bark generally requires 1 lb actual N per cubic yard, to avoid nitrogen deficiency on plants subsequently produced in the mix. Fresh hardwood bark in the Midwest, requires at least twice as much N. Fresh pine bark can be composted in stacks (15 ft wide × 8 ft high) in 6 weeks, whereas fresh hardwood bark requires 12 weeks before all the nitrogen is utilized. Heat produced during composting is generated by microorganisms involved in breakdown, mostly of cellulose.

Large quantities of pine bark are utilized in the U.S. without composting. It has been found that plant pathogens can survive in bark stacks to which nitrogen has not been added. The temperature in large areas of such stacks seldom exceeds 80°F, although the center of these piles, frequently, may self-heat to higher temperatures. Pathogens, therefore, may survive in this non-composted bark and cause problems in production if used without adequate precautions.

Other factors, in addition to pathogen reduction or elimination, that contribute to the absence of root diseases on plants produced in bark compost are antagonistic microorganisms and chemical(s) with properties similar to fungicides. Controlled laboratory tests now have shown that *Phytophthora* root rot is

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[1] Supported in part by grants from The Fred C. Gloeckner Company, Inc., 15 East 26th Street, New York, N.Y., and Mead Paygro, First National Plaza, Dayton, Ohio 45402. Approved for publication as Journal Article No. 95-76 of the Ohio Agricultural Research and Development Center, Wooster.

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suppressed in composted hardwood bark. This means that if a low inoculum level of *Phytophthora cinnamomi* is introduced, plants are not killed in compost. Identical levels would kill plants in peat media. In another study it was found that *Fusarium* cutting rot and wilt of chrysanthemum also is controlled in compost. Those plants became infected when high inoculum levels were used, but they were not obviously damaged. Control of *Fusarium* in compost is equal to control in sterilized peat after two drenches with Benlate (Figures 1 and 2). Research at the University of Illinois has shown that com-

Figure 1. *Chrysanthemum* × *maritalium* 'Yellow Delaware' (received from Yoder Bros., Barberton, Ohio) in a peat-sand-perlite medium inoculated with *Fusarium oxysporum* f. sp. *shrysanthemi*: 1) Uninoculated; 2) low inoculum level, (note some wilting); 3) high inoculum level, (noted dead plants); and 4) high inoculum level drenched with Benlate (note chemical control).

Figure 2. *Chrysanthemum* × *morifolium* 'Yellow Delaware' (received from Yoder Bros., Barberton, Ohio) in composted hardwood bark-sand medium inoculated with *F. oxysporum* f. sp. *shrysanthemi*. Note absence of disease symptoms as compared to plants in Figure 1.

posted hardwood bark also is suppressive to nematodes. In Japan, composted tree bark and sawdust is used to control *Fusarium* diseases of field and greenhouse vegetables and ornamentals. Findings discussed here are reminiscent of results obtained by various plant pathologists with sterilized peat mixes that were amended with microorganisms antagonistic to plant pathogens.

Present research at the OARDC is focusing on the role and identity of microbial antagonists and chemicals involved in suppression of root pathogens. Antagonists have been isolated from various soils and composts and will be added during the composting process, hopefully, to yield a final product with predictable disease suppressive properties. Another study involves the composting process itself. The effects of nitrogen source, pH, temperature, aeration and other factors are being tested to reduce the length of time for composting.

Although composted hardwood bark is used successfully by some nurserymen, specific guidelines for successful production of floral crops are lacking. Physical properties of composted bark, fertilizer amendments (particularly nitrogen) and the overall economics of bark as opposed to peat need to be investigated before final recommendations can be made to these growers. Composted hardwood bark also needs to be compared with pine bark that presently is more widely distributed.

Hardwood, and contrary to a commonly held opinion, some softwood barks contain substances that are toxic to various plants. Research at the OARDC, in Norway, and at the University of Illinois has shown that these inhibitors can be destroyed by composting. These chemicals in fresh bark are most toxic to germinating seeds and seedlings. Bedding plant producers therefore, should be particularly careful and test the bark for inhibitors to their plants. These inhibitors appear to be the major limiting factor for successful use and is an area that we expect to study in greater detail. Hardwood bark available in Ohio needs to be composted (2 to 3 lbs N per cubic yard fresh bark) for at least 10 weeks during the warmer months in the year. In the winter, larger piles and a longer composting period is required to destroy the inhibitors.

SURREY NURSERY STOCK PROPAGATORS

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The Surrey nursery industry produces about 12% of the total of hardy nursery stock produced in the United Kingdom. It is an area of mainly small wholesale growers situated to the Southwest of London.

HISTORY OF THE INDUSTRY IN SURREY

The nurseries developed in the 18th and 19th centuries when English landscape gardening was at its peak and various plantsmen were introducing new plants, especially from America. The result of this was "American Specialist" nurseries, such as Waterers, Veitch and J. Gordon.

Since the 19th century the area has had a chequered history. The first mail-order nursery in the U.K. started in the Surrey area in the 1920's. This was at the same time as a soil embargo was started when selling to the United States. Today the area is going through change; container production is on the increase and the nurserymen have to compete with larger wholesale nurseries in other parts of the country.

THE AREA TODAY

The area today still mainly consists of small wholesale nurseries, but these are mainly specialist growers. It is impossible to mention all the nurseries or even all the specialisms, but the following nurseries illustrate the type of small specialist growers which exist in the area.

Hagthorne Cottage Nurseries. Hagthorne is a 1 ha nursery producing 16,000 miniature roses. Grafting is preferred to cuttings as cuttings produce weak plants which only last 2 to 3 years before deterioration starts. Grafting is by a single-bud graft.

Waterers of Bagshot. This nursery has a total of 70 ha and is the wholesale member of the Waterers group. The nursery produces 20,000 rhododendrons, of which 30% are *Rhododendron yakushimanum* hybrids.

In the early 1950's, the late Percy Wiseman commenced crossing this rhododendron with other compact-growing large-flowered hybrids to produce dwarf, free-flowing plants which he felt would be suitable for the small gardens of the future.

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[1] Lecturer in Nursery Practices.

Gradually the desired results materialized and the first generation hybrids were released in 1958, followed by the second in 1964/65. Waterers are now starting to release the third generation.

Windlesham Court Nursery Ltd. Windlesham Court is a 2 ha nursery which started producing heathers 8 years ago. They are the main specialists of this crop in the United Kingdom. Production takes place in 4.3 × 27.5 m tunnels; 50 tunnels are erected on the nursery and each tunnel holds 12,000 heathers.

The key to growing at Windlesham is simplicity and speed although a number of problems had to be overcome. One of these, *Phytophthora cinnamomi*, is fairly common in the U.K., but Windlesham is free of this disease by having a routine cleaning programme. Before production, all structures are sterilized and stock plants checked for cleanliness. Another problem for growers, and especially heather specialists in Surrey is the high pH (7.5) of mains water. Due to this a Waterwych de-ionizer is used. Water, having passed through a de-ionizer, has a pH of 4.5.

Normandy Ground Covers. This 1.5 ha nursery is a wholesale grower with a turnover of 60,000 ground cover plants, most of which are grown in polythene plants rolls. Rolls have been found to be convenient and quick for contract planting. Rooted cuttings are transplanted into the roll which contains an Osmocote container mix. Plants can be removed from the rolls quickly with the minimum of root disturbance and can be planted in narrow space nicks. Root depth in the roll is superior to the usual shallow pot-balled plants with the result that establishment is excellent even in dry weather.

Round Pond Nurseries. Round Pond is 3 ha intensive wholesale production unit on the northern edge of the main Surrey hardy nursery stock area that specializes in deciduous azaleas. Production takes place in 4.3 metre wide × 27.5 m long tunnels. These are covered with film plastic. To aid the operation of cladding, a special fixing strip, the Goffton strip, is used to hold the plastic film in position and, therefore, obviates the need for buying in plastic; this means that the polythene is reusable. To ensure a clean and hygienic production area, the whole site of the tunnel complex has been drained with open drains filled with stone.

Propagation is in a 6.7 m × 27.5 m long tunnel. This house has four concrete pads 12.2 metre long by 1.8 metre wide which have thermostatically controlled heating cables embedded in them. All propagation takes place in plastic trays which *stand on the concrete beds. These beds have a crossfall of 50* mm to ensure good drainage. Mist lines are suspended from the

house superstructure to ensure an unobstructed work area.

Production of azaleas is on a 2 year cycle. Stock plants are planted in a structure which is closed in January to encourage growth; at the same time a base dressing and a mulch of spent hops is given to retain moisture.

EDUCATION IN SURREY

The nurserymen mentioned are five members of the Surrey Hardy Nursery Stock Discussion Group. This group meets on an informal basis once a month to discuss topical matters. Meetings take place at Merrist Wood Agricultural College, Worplesdon, Guildford, which is situated on the southern edge of the nursery area.

Merrist Wood is one of three colleges (the others being Hadlow and Pershore) which train nursery students to the level of the Ordinary National Diploma (3-year course). The College has 300 full-time students and gives courses in Agriculture, Arboriculture, Landscape Construction and Nursery Practices.

The College serves the industry in a number of ways. Apart from educating students at all levels for the industry it also acts as a Conference Centre as well as having close liaison with the industry on project work which is carried out by third-year nursery students. Such projects include, for example:

Ericaceous Compost Trials: For a number of years the College and some growers in the areas have had problems with growing plants in containers. To try and solve these problems a trial was started in 1973 to look at the range of composts being used and the effect of the compost on plant growth. Results so far have been variable but a number of important points have arisen. These include the importance of checking sand pH and free lime content, especially when the College water pH is 7.5. Various methods have been tried to reduce pH, including the use of choline phosphate which is new to the British market. Choline phosphate can reduce the pH by 1.0, but increases the phosphate levels in the compost.

Other projects have included looking at new methods of propagating *Nothofagus*, the use of peat blocks for propagation, and comparing different budding techniques for tree production.

Wednesday Afternoon Session, August 25, 1976

The Wednesday afternoon session convened at 1:30 p.m. with Dr. Harold Tukey serving as moderator.

PRODUCTION SHOOT-TIP CULTURE (MICRO-PROPAGATION)

MARK CUNNINGHAM

Cunningham Gardens, Inc.
Waldron, Indiana

What does tissue culture really mean to the propagator? Tissue culture is a procedure in which an excised plant part is placed on an appropriate sterile culture medium, managed under controlled laboratory conditions, grown in a special disease-free environment, and ultimately develops into a new plant.

In starting a tissue culture laboratory, there should be sound objectives to justify the expense of setting up the costly facility and delegating trained personnel for its year 'round operation. Also, one must set up goals and reasons for operating the laboratory. Two important reasons for investing time and money into this type of project are:

I. Recovery of Disease-free plants. This is probably the most important reason for getting into tissue culture. By removing virus, bacterial and fungus pathogens which invade the plants, chances are vastly greater in restoring the plant or cultivar to its normal vigor and state of productivity. I must point out that by tissue culturing a plant, we are not assured of making it 100% disease-free. It is necessary to go through a complex indexing program before the plant is assured to be completely disease-free, but we find almost complete freedom from disease problems through the first culturing, and virtually none in successive generations of culture. We, therefore, try to culture basic stock once each year.

II. Rapid Clonal Multiplication. By using tissue culture techniques, one is able to rapidly increase plant production. This is very important to the grower who has plants that are slow and hard to propagate. Tissue culture also enables the grower to introduce new cultivars into the trade much sooner via this rapid means of multiplication. Another factor of tremendous economic significance is our ability to micro-propagate some plants, such as *Hosta* and *Gypsophila* every month of the year, as opposed to seasonal propagation with many of our herbaceous plants.

Our laboratory facility consists of a medium size room (16′ × 24′) divided into four smaller rooms: transfer room, chemical mixing room, growing room, and office record-keeping area.

Light, temperature, and nutrient media are the factors which control the proliferation of plant growth.

LIGHT: For shoot growth, low light intensity — around 100 ft-c (100 lux) — is used. High light intensity of 1000 ft-c (10,000 lux) is used for rooting. We use Gro-Lux lights, both wide spectrum and regular, controlled for a daylength of 16 hours. This daylength requirement can be varied if a given plant requires a different light period.

TEMPERATURE: The laboratory temperature is maintained at 70°F. The lights, however, create heat and, therefore, the laboratory requires air-conditioning for correct temperature control. The system is electrically heated, and all air is electronically filtered. So far we haven't varied the temperature but some plants might require other temperatures.

NUTRIENT MEDIA: The chemical nutrient medium consists of a modified Murashige-Skoog, using inorganic nutrients, vitamins, auxins, cytokinins, and agar. By modifying the auxin and cytokinin levels, shoots or roots are initiated. We prefer media which induce multiple shoots, thus giving us more rapid increase.

Stage I: The first step is the establishment of aseptic culture. Whatever plant part is used, certain procedures must be used in cleaning the plant. A Clorox solution (1-10 ratio) can be used for the washing cycle. The length of time for the washing can vary from 2 to 30 minutes depending upon the plant species. After washing comes rinsing, usually 2 times in sterile distilled water, then the shoot-tip or other plant part is placed in the test tube. In chrysanthemum and gypsophila, the shoot-tip is deep in the leaf-covered, growing point, so little contamination occurs. In fact, under our system, contamination has never been a problem.

Chrysanthemum × *morifolium* (garden mums), *Gypsophila paniculata* 'Bristol Fairy', *Ajuga* 'Burgundy Glow', *Phlox subulata* (creeping phlox) and *Dicentra spectabilis* (bleeding heart) are established by removing the shoot-tip from the growing point of the plant. In *Hosta plantaginea* 'Grandiflora' and *H. decorata* 'Thomas Hogg', the buds that develop below the soil surface are used in initially establishing the culture in stage I. The hostas are particularly hard to clean up for culture because the source of the original start comes from dormant buds which are under the soil surface. Persistent scrubbing in the Clorox solution is required prior to removal. We prefer starting with the dormant bud than with the juvenile bloom shoot, which some technicians use.

Stage II: After the plant has been established in the test tube and has grown for approximately one month, the next step involves separating the shoots, or dividing the plant, for further multiplication. At this same time, some shoots can also be

placed on the appropriate nutrient medium to promote roots.

Stage III: Two or three weeks after the plant is placed on the rooting medium, roots form. This is the step in which transition is made from the laboratory environment — the operation in which rooted plants are transferred from test tubes to the greenhouse. In order for the plant to adapt to its new environment (varying temperatures, moving air, and higher light intensities), the plant must go thru a re-adjustment period. This growing-on stage, in a sense, is similar to transplanting tender, fragile seedlings. Our procedure is to dibble them into small peat pots and place them under mist for 1 week or less; the survival rate is 100%. As plants quickly develop, they are shifted up to larger containers, or planted into stock beds for normal propagation procedures.

Micro-propagation (tissue culture) is a tool the modern plant propagator should not fail to use for producing plants, both for economic reason and for product-improvement. It is a must today. Not all plants respond to this system, but for those which do, we feel should be managed via tissue culture. As research continues there is promise many of the woody species will also be produced via tissue culture.

TISSUE CULTURE PROPAGATION OF DAYLILIES

CHARLES W. HEUSER and JOHN HARKER

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

The Liliaceae is composed of many herbaceous perennial plants. It includes lilies, iris and other commercially important ornamentals. One flowering ornamental group, the *Hemerocallis*, known in the trade as daylilies, have been popular as herbaceous perennials for many years. The standard method of propagation is through division (1,2,4,6). This procedure, while it yields plants that are true-to-type, is a slow method of asexual propagation. The slow nature of propagation by division results in the better new cultivars never reaching the commercial market but remaining in collector and breeder gardens. We now describe a tissue culture method for rapid clonal multiplication of daylilies. When properly employed, the method yeilds uniform plants without genetic deviation.

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MATERIALS AND METHODS

Tissue Source and Preparation. Flower buds measuring 0.5 to 1.0 mm in height are best as explants. Smaller buds were found to be less reliable and larger buds split open at the apex allowing the entry of microorganisms and thrips. Buds at this stage have a hard waxy covering and are free of most microbial contaminants. The buds are dipped for 2 to 3 sec in 95% ethanol prior to disinfection for 10 to 15 min in a 20-fold dilution of Clorox. After disinfection the buds are removed from the Clorox solution and rinsed three times with autoclaved water. From this stage on, all procedures should be performed under aseptic conditions. After sterilization, the buds are disected into individual parts. The three outer sepals and three inner petals are transferred to the nutrient medium. If tissue is in short supply, the six filaments can also be used for callus initiation.

Media. Three different media are necessary for the tissue culture of daylilies, one for each of the three steps in vitro: (1) the establishment of the initial callus from the bud explant; (2) the subsequent shoot multiplication step; and (3) the development of roots on the multiplied shoots. The Murashige and Skoog salt mixture (5) forms the basis for the media used in the three steps. Table 1 lists the other constituents employed at each step.

Table 1. Nutrient addenda employed in *Hemerocallis* tissue culture propagation.

Step I		Step II		Step III	
Compound	mg/l	Compound	mg/l	Compound	mg/l
Thiamine HCl	0.5	Thiamine HCl	0.1	Thiamine HCl	0.1
Nicotinic Acid	0.5	Kinetin	0.1	Nicotinic Acid	0.5
Pyridoxine HCl	0.5	Nicotinic Acid	0.5	Pyridoxine HCl	0.5
2,4-D	1.0	Pyridoxine HCl	0.5	IAA	1-10.00
Kinetin	1.0	i-Inositol	100.0	i-Inositol	100.0
i-Inositol	110.0	Adenine Sulfate	160.0	Agar	8,000.0
Casein Hydrolyzate	1,000.0	KH_2PO_4-H_2O	300	Sucrose	30,000.0
Agar	8,000.0	Casein Hydrolyzate	1,000.0		
Sucrose	30,000.0	Agar	8,000.0		
		Sucrose	45,000.0		

Agar formulations are utilized for the tissue culture of daylilies. The use of liquid is not recommended because of poor results. The tissue culture medium after adjusting the pH to 5.6-5.8 is autoclaved 15 min at 120°C (18 lbs pressure). In step I, the nutrient medium is placed in 4 oz french square bottles in 25 ml aliquots. For the shoot multiplication step 125 ml Delong or Erlenmeyer flasks with 50 ml of nutrient solution are utilized. Step III, the rooting stage, is carried out in 16 × 150 mm culture tubes with 5 ml of nutrient solution.

The shoots, after rooting, are treated as young seedlings and planted in a soil, peat and perlite mixture (1:1:1). The

plantlets should be placed under shade approximately 2 weeks. Mist was found to be detrimental and should not be utilized.

Environmental Conditions. Step I, callus initiation, is carried out at 29±1°C without light. Cultures in the multiplication and root initiation steps are illuminated 16 hr daily with approximately 100 ft-c. Temperatures in steps II and III are held at 26-27°C.

RESULTS AND DISCUSSION

Since our initial report (3) on the multiplicaiton of the daylily cultivar 'Chipper Cherry' the method has undergone considerable change. The revised procedure forms the basis of this report. The cultivars (consisting of both diploids and tetraploids) successfully propagated are found in Table 2.

Table 2. *Hemerocallis* cultivars propagated through tissue culture.

Cultivar	Ploidy Level*
'Chipper Cherry'	D
'Ed Murray'	T
'Hope Diamond'	T
'Little Wart'	D
'Mary Todd'	T
'Purple Robe'	T
'Red Siren'	D,T

* D = Diploid, T = Tetraploid

Callus initiation in stage I is slow and may take 8-12 weeks. At this time, the callus may have the appearance of organized masses. In stage II the concentration of applied hormones greatly influences the formation of shoots. Varying the kinetin concentration from a low of 0.1 to 30.0 mg/l results in a strong inhibition of shoot production as the kinetin concentration is increased. The best shoot production occurred at the lowest (0.1 mg/l) concentration. The auxin compound and concentration are also changed in step II. Initial experiments utilized 2,4-D but the production of some aberrant plants, as indicated by the presence of variegated foliage, resulted in a change to NAA. As with kinetin, lower levels of auxin were more promotive of shoot production. An NAA concentration of 0.5 mg/l gives satisfactory shoot production. Roots sometimes develop at the same time as shoots are formed. The roots, however, are often not attached directly to the shoots but to an intervening piece of callus. When this condition exists, the shoots should be separated from the callus mass and rooted. Attempts to establish plants in soil without roots attached directly to the shoot often leads to failure.

The initiation of roots on the shoots (stage III) is promoted by the presence of an auxin in the medium. As shown in Table

3, the shoots will develop roots without auxin but the presence of auxin substantially increases the root number. As is also shown in Table 3, the concentration of auxin is not a critical factor.

Table 3. Rooting response of hemerocallis plantlets to indoleacetic acid.

IAA Concentration	Roots/Shoot
0	1.6
1.0	3.8
5.0	4.0

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RAPID IN VITRO GERMINATION OF IMMATURE, DORMANT EMBRYOS

MARK R. ZILIS and MARTIN M. MEYER

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The germination and development of embryos *in vitro* on a defined medium is one of the oldest techniques of *in vitro* culture of plants for propagation purposes. Embryo culture was first shown to have promise for rudimentary embryos of orchid when Knudson (3) developed a nonsymbiotic method of germinating orchid seeds on a sterile medium. Up to that time, orchid seeds were germinated in conjunction with a fungus which gave a very low percentage of plants.

Plant breeders, particularly of fruit trees, were some of the early advocates of test-tube culture of plant embryos. They found that some crosses, which normally did not set seeds due to embryo abortion, would produce seedlings if the embryo was excised and grown *in vitro*. Tukey (7) made considerable use of this technique and developed media for fruit tree embryos. Lammerts (4) produced dramatic increases in the breeding programs of fruit trees, camellias, and roses using embryo culture.

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RAPID IN VITRO GERMINATION OF IMMATURE, DORMANT EMBRYOS

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The germination and development of embryos *in vitro* on a defined medium is one of the oldest techniques of *in vitro* culture of plants for propagation purposes. Embryo culture was first shown to have promise for rudimentary embryos of orchid when Knudson (3) developed a nonsymbiotic method of germinating orchid seeds on a sterile medium. Up to that time, orchid seeds were germinated in conjunction with a fungus which gave a very low percentage of plants.

Plant breeders, particularly of fruit trees, were some of the early advocates of test-tube culture of plant embryos. They found that some crosses, which normally did not set seeds due to embryo abortion, would produce seedlings if the embryo was excised and grown *in vitro*. Tukey (7) made considerable use of this technique and developed media for fruit tree embryos. Lammerts (4) produced dramatic increases in the breeding programs of fruit trees, camellias, and roses using embryo culture.

A recent development in embryo culture utilizes the *in vitro* technique to germinate seeds with particularly complicated dormancy mechanisms. The dormancy giving the greatest problems belong to seeds containing rudimentary or immature embryos. The embryo is small and must develop using food stored in the endosperm. Other dormancies may further complicate rapid germination. Hu (2) reported in 1974 that *Ilex* embryos grew rapidly and germinated precociously using embryo cultures. This technique saves several years in breeding programs by shortening the generation time.

Two genera of plants, *Paeonia* and *Viburnum*, whose seeds possess difficult dormancies, have been studied at the University of Illinois. The embryos of both are minute, remaining in the rudimentary stage of development when the seeds are dispersed. Peony seed must first undergo a warm, moist stratification for embryo and root development and moist chilling to overcome epicotyl dormancy. Many peony seeds may take 2 years to germinate.

Germination of *Viburnum* seed (1) follows a pattern similar to the peony — warm stratification for root development followed by a period of moist chilling. A few species, however, need only a cold treatment. Viburnum seed germination takes 2 or more years. Peony and viburnum seedlings have been produced in a relatively short time through embryo culture.

Excising the embryos of peony and viburnum seed follow similar techniques. First, the seeds are sterilized in a 10% Clorox solution for 15 to 20 minutes. The embryo half of the peony seed is removed by a wire stripping tool followed by seed coat removal. The endocarp is peeled off the viburnum seed without cutting it in half. The remaining seed parts containing thę embryo are soaked in 10% Clorox for 20 minutes. The seed is then placed in plastic petri dishes and moved to a sterile chamber where the final extraction fo the embryo takes place.

All tools for further extraction are sterilized in 70% ethanol. A scalpel is used to remove the endosperm on either side of the peony embryo. At this point, with viburnum seeds, the endosperm is cut in half and the remaining endosperm is scored above the embryo without cutting through the embryo.

Tweezers are used to grasp the seed on each side of the embryo. The endosperm is bent until the embryo is exposed. A small spatula tool or dental probe can be used to remove the embryo. If the endosperm does not break cleanly, the embryo can usually be teased from the endosperm without injury. Finally, the embryo is inserted into the test tube containing the sterile medium. The tubes are placed under cool white fluores-

cent lights at 300 ft-c. The temperature is maintained at 80°F.

A modified Linsmaier-Skoog (5) medium without hormones or optional constituents was used. Hu (2) found this worked well with *Ilex* embryos. The modified medium contains a higher sucrose (40 g/l) and salt level than the early workers used in embryo culture. It also contains inositol and thiamine HCl, not found in earlier media. The medium was found to be superior to Knudson's or Knopp's in the embryo culture of *Paeonia lactiflora* and *P. suffruticosa. Only 6 g of agar were* used to prevent suppression of growth of the embryo as found by Stoltz (5).

Peony embryos grow rapidly with cotyledons appearing and the root axis reaching 3 to 4 inches in 6 to 8 weeks. At this time, however, the seedling exhibits epicotyl dormancy. A cold treatment for 4 to 6 weeks is necessary to produce the first set of true leaves.

Viburnum seed embryos grow without a cold treatment. There are noticeable changes in embryo size within 24 hours. The radicle protrudes into the medium after 1 week. By the 44th day, the seedlings usually have grown one or two sets of true leaves and can be transplanted.

Peony and viburnum seedlings should be planted without delay. Leaving them in the tubes too long cuts down on survival. The small plants are pulled out of the agar with long forceps, washed off in distilled water to remove clinging agar and planted into a mix of 60% coarse sand, 20% soil and 20% peat moss. Peony seedlings are watered and moved to a greenhouse growing bench. Viburnum seedlings need 5 to 7 days on a mist bench to harden them before moving to a growing bench.

Embryos of Viburnum lentago, V. lantana and V. burkwoodii have been cultured and successfully transplanted. *Paeonia lactiflora,* a herbaceous peony, and *P. suffructicosa,* the tree peony, respond well to embryo culture.

Growing time for seedlings of both genera is cut down dramatically. *Viburnum lentago,* the nannyberry, may take 1 to 2 years to germinate under natural conditions. Seedlings of *V. lentago* can be produced in 45 days by culturing its embryo. This can shorten a breeding program many times.

Thus, *in vitro* embryo culture can be a handy tool for the nurseryman. From its earliest uses with orchids and abortive embryos, it has made possible the consistent propagation of many plants seldom grown by seed. Seeds with complicated dormancy problems caused by rudimentary embryos can produce seedlings easily by embryo culture.

If the excised embryos are raised with hormones in the

medium, masses of callus can be formed. This callus is useful for developmental studies of plants from true tissue culture. Herbaceous perennial plants have been developed from callus as *Iris*, *Hemerocallis*, and *Hosta*, in our laboratory. We hope to use callus to propagate large quantities of more woody perennials in a short time. The growth of embryos *in vitro* can be a valuable tool for studies of tissue culture propagation by other methods.

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ADVANCES IN TISSUE CULTURE: RAYFLOWER AND PROTOPLAST CULTURE[1]

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INTRODUCTION

Culture of organs, tissues, single cells and protoplasts has been used to solve many problems including improving propagation time and increasing clones, developing new clones, growth regulator and physiological studies and producing disease-free clones. In our laboratory these techniques have been used for reduction of time for propagation, increasing clones, physiological and growth regulator effects and plant

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improvement of asparagus and freesia; in addition, separating chimeras and protoplast culture are being studied on dahlias. This paper is a preliminary report of our findings, techniques and of investigation underway, together with a brief review of research in tissue culture.

Asparagus: We will discuss asparagus tissue culture in some detail because its development has elements common to tissue culture in many species. Asparagus is a dioecious plant. The yield varies between sexes, male and female plants being morphologically different, and even varies among plants within the same sex (19). Propagation by seed produces populations less suitable for commercial production than asexual propagation, unless male seeds can be readily obtained. However, dividing crowns takes too much time and labor for commercial production. Aseptic culture of asparagus (20,25,30,31,40) appears promising for increasing desirable clones which could be used in commercial plantings.

Various organs and tissues including the meristem (20,25,30,31,40), stem segments with one lateral bud (40), and lateral buds (15) have been cultured successfully on artificial agar media with suitable nutrients, vitamins and growth regulators. Plantlets from callus were eventually transplanted to the field. Our work using lateral bud culture (15) utilizes the following procedures, many of which are common to most tissue culture approaches.

Lateral buds are excised after surface sterilization (20,25,30,31,40) and cultured on agar or liquid medium. Our surface sterilization is a modification of Basile's (3) method. Buds are surface sterilized in aseptic test tubes containing 0.5% NaOCl with a few drops of Tween 20. The solution is moved in and out with a sterile syringe 3 to 4 times for good contact with the tissue, then rinsed in sterile, deionized, distilled water. Three buds are transferred onto 50 ml of modified Murashige and Skoog (24) medium (MMS) in 125 ml Erlenmeyer flasks which were previously autoclaved at 121°C for 20 minutes and the pH adjusted to 5.8 ± 0.1 with either 1N NaOH or 1N HCl after 10 minutes in solution. The tissues are incubated under cool white fluorescent lights of 100 ft-c at 25°C for 16 hours per day.

We studied the effect of auxin and cytokinin on callus formation and organogenesis using all combination (4 × 4 factorial design) of NAA and kinetin at 0, 0.01, 0.1 and 0.5 ppm. We found that both growth regulators play an important role in callus and plantlet formation. The combination of NAA and kinetin at 0.1 mg/l promoted callus formation. If callus was not sub-cultured, shoots and roots would differentiate and form

complete plantlets. NAA and kinetin alone had less effect on callus formation, callus growth and plantlet formation than when in combination (15). Callus could be multiplied by dividing callus into several small pieces before plantlets developed (approximately every 2 weeks) and transferring onto an agar or liquid medium containing 0.10 mg/l each of NAA and kinetin. When liquid medium is used, shaking or rotating provides satisfactory aeration for the tissue.

Plantlets could be induced by directly culturing or subculturing callus on an agar medium for 4 to 6 weeks (Fig. 1). They then could be transplanted to soil after acclimating to the new environment (20,40). An auxin-free medium or incubating under high light intensity (20) before transplanting aided in the success of transplanting. We have transferred asparagus plantlets directly from the flask to moist peat under cool white fluorescent light at room temperature. The first week they are watered with MMS solution without growth regulators, followed by tap water the second week. The plants can then be placed in the greenhouse.

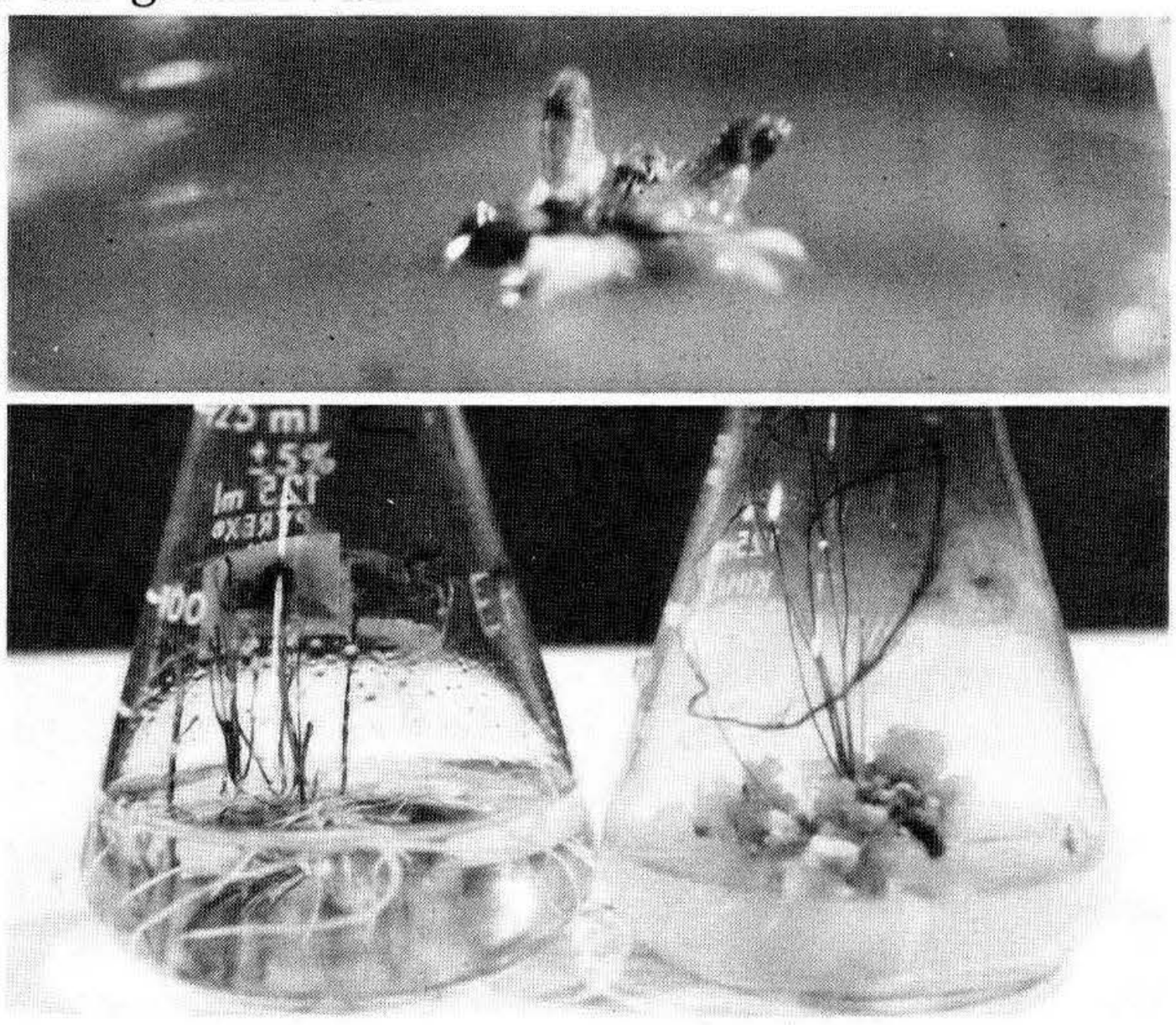

Figure 1. Above: Asparagus plantlets induced from lateral buds cultured on an agar medium.
Below: More advanced plantlets in liquid and agar media (note roots readily visible in liquid medium).

Dahlia: *Dahlia variabilis* L., a species native to Mexico, is a popular garden flower with a wide color range and frequently has natural chimeral mutations which may appear as variegated colors (Fig. 2). Our efforts with dahlia chimeras are aimed at separating chimeras which are evidenced by single cells or cell group differences. In chimeras of this sort the mutated parts cannot be separated as easily as when the mutation affects an

entire organ or part of an organ. Such is the case with variegated flowers and variegated leaves, and we are attempting special methods including surgical techniques and tissue culture to attempt to isolate the components of some of these mutations.

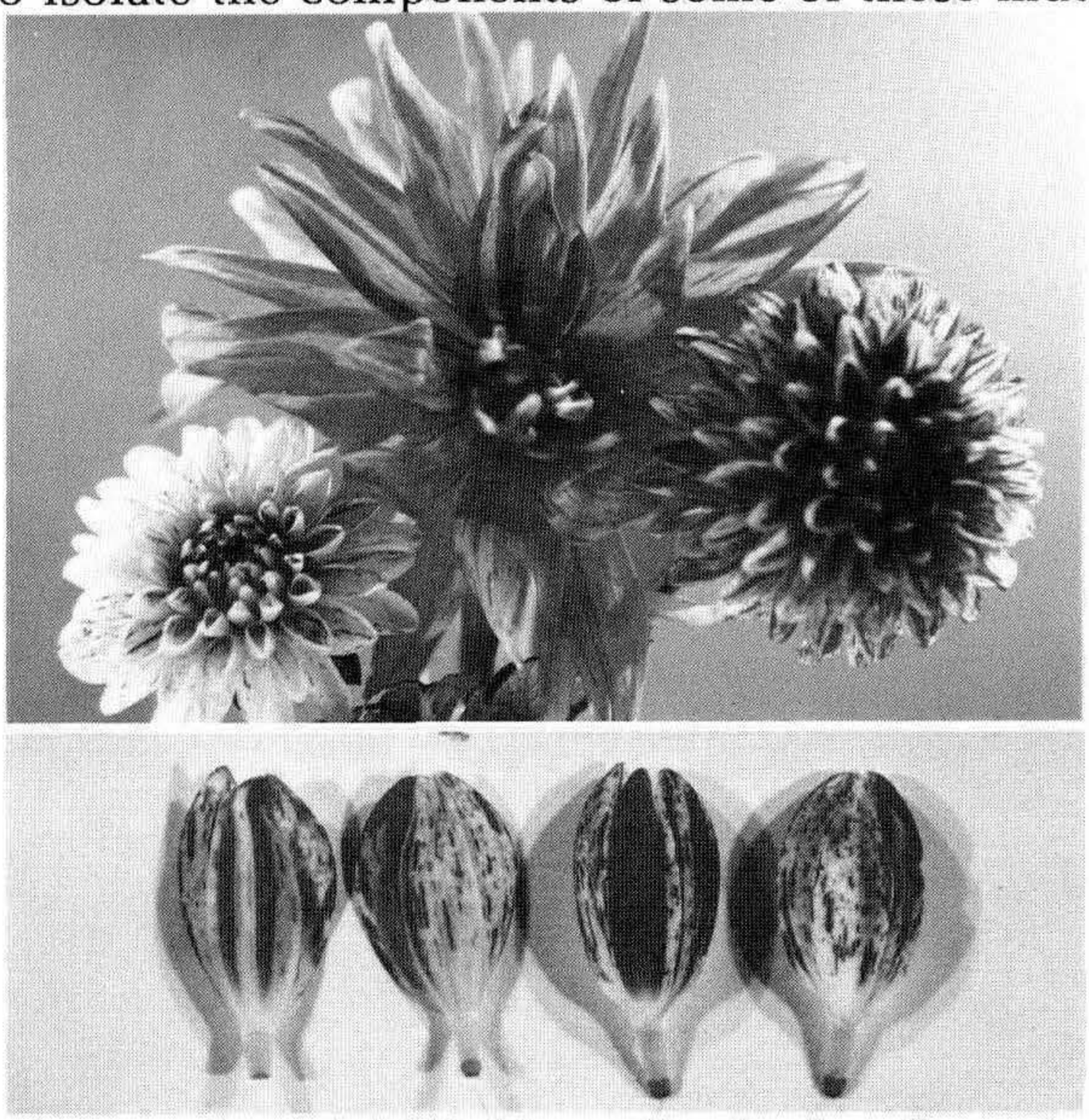

Figure 2. Above: variegated dahlia blooms (heads of ray flowers)
Below: ray flowers removed from a bloom of 'Frosted Plum'.

We are currently attempting this approach with two dahlias, 'Nita' and 'Frosted Plum', which show chimeras occurring in the ray flowers. Fresh sections of ray flowers 30 to 50 microns thick observed under the microscope illustrate that the chimeras occur primarily in the upper and/or lower epidermal layers but do not occur in the mesophyll (middle) layers. Both single cell and cell group chimeras are clearly visible in the sections, the upper epidermal layer usually has more chimeras occurring than the lower epidermal layer. Even though chimeras in plants such as 'Nita' or 'Frosted Plum' do not show variegation in the leaves, it seems possible that the genetic message may be differentially distributed in the leaves. Therefore, our experiments have attempted to use both leaves and ray flowers. Techniques which appear most promising to separate and propagate chimeras include (a) selecting plants from non-selective tissue culture, (b) surgical separation and culture of the mutated tissues *in vitro*, or (c) isolation of single cells and/or protoplasts and subsequent culture.

SELECTING PLANTS FROM TISSUE CULTURE

Leaf epidermal tissue has been demonstrated to differentiate buds and roots in several plant species (5,12,33,34).

When leaf discs were placed onto a suitable medium, callus formed at the cut edge and on the surface of the leaf (33,34). Shoots and roots developed after the callus was formed. The shoot buds were formed from the epidermal cells but the roots originated internally. The shoot and root formation was regulated by auxin and cytokinin levels (5,12,33,34).

Dahlia leaves were prepared using techniques similar to those described for asparagus bud culture (15). Leaf segments 0.5 × 1.0 cm were utilized in a 4 × 4 factorial design of NAA and kinetin added to the MMS high salt medium, as with asparagus, with thiamin HCl 0.5 mg/l, pyridoxin HCl 0.5 mg/l, nicotinic acid 0.5 mg/l, glycine 2 mg/l, myo-inositol 100 mg/l, sucrose 30 g/l and agar 4.0 g/l added. Callus formed initially at the cut surface edge of the leaf segment and subsequently on the surface of the leaf segment after 2 weeks of incubation. Thus callus formation was observed on the medium containing both NAA and kinetin at 1 mg/l. Leaf segments containing midrib tissue formed larger amounts of callus than those without the midrib. Apart from that, there was no effect of selecting the leaf segment from various parts of the leaf, tip, middle, and basal portions responded equally to the growth regulators in the medium. 'Frosted Plum' formed callus earlier and more uniformly than 'Nita'. Roots formed on 'Frosted Plum' leaf segments after 4 weeks but rarely or not at all on 'Nita' leaf segments. No shoots have produced from leaf segment callus of either cultivar, even though a wide range of growth regulator levels have been attempted.

Ray flowers: Ray flower segments and ray flower peels have been cultured successfully in chrysanthemum (5). Bush *et al.* found that the basal portions of chrysanthemum ray flowers were best for callus and plantlet formation. The plants obtained from ray flower culture, whether from segments or peels, were variable and not reproductions of the parent plant. Many different types of plant and flower forms resulted. We have tried to separate chimeras by culturing ray flower segments and peels. These studies have been conducted under both light and dark conditions using procedures similar to those used for leaf segments and asparagus culture with the following modifications. Ray flowers were surface sterilized in 95% alcohol (ETOH) 1.5 min before treating with NaOCl — Tween 20 for 10 min. Tissues were rinsed 3 times with sterilized deionized distilled water and cut into 3 portions, tip, middle, and bottom (not including ovarian tissue) and transferred onto 50 ml of modified Linsmeier and Skoog medium in 125 ml Erlenmeyer flasks. Growth regulators used were all combinations of NAA at 0, 0.3, 3 and 9 mg/l and 6-benzylamino purine (BA) at 0, 0.03, 0.3 and 3 mg/l which were added to the medium before autoclaving and

then placed under conditions of 16 hours light at 100 ft-c or in 24 hours of darkness. Although segments increased in size and began to produce small amounts of callus (rays from open flowers) and large amounts of callus (rays from buds not yet open), no successful plantlet production has resulted to date.

SURGICAL SEPARATION AND CULTURE IN VITRO

The results from our preliminary work showed that the variegation occurred locally in epidermal layers only. Bush *et al.* reported that peels of epidermis of chrysanthemum ray flowers could be cultured and produce plantlets, while shoots and roots from epidermal layers in culture have been recently investigated (33,34). For epidermal layer culture *in vitro* to be successful, sub-epidermal layers must be present (7). The growth regulators used play an important role in organogenesis (7,33,34). We are currently investigating surgical techniques to separate chimeral portions of ray flowers, either using only epidermal layers or epidermal layers with mesophyll layers, using methodology similar to that described for ray flower culture.

ISOLATION AND CULTURE OF SINGLE CELLS OR PROTOPLASTS

Single Cells. If plantlets are obtained from single cells, plantlets usually vary dramatically because of the variation in the location of the cell taken from the parent plant. It is possible that screening these plants could separate chimeral plants from normal plants. Methods of single cell culture have been studied in several plants including asparagus (30,38), sycamore (23) and others. Two main groups of methods have been classified, either mechanical or enzymatic. Mechanical isolation is done by methods such as grinding the tissues (16), microsurgically separating the tissue (2), shaking callus or rotating callus in liquid medium. Enzymatic isolation has been used successfully in some cases (8,32). A more advanced technique has been developed by using EDTA (8), or adding potassium dextran sulfate to the enzyme solution to improve yield of single cells (32). Dahlia callus has been placed on liquid medium (Linsmeier and Skoog) containing 1 mg/l of both NAA and kinetin and placed on a shaker at 100-125 rpm. So far, little isolation of single cells has occurred under these conditions, and our research plans for the future involve selection of different media and utilizing other techniques of isolation of single cells using enzymes such as pectinase.

Protoplasts. Plant protoplasts are intact cells with the cell wall removed. It is difficult to obtain a large amount of protoplasts which are intact and viable. In general, two methods have been used with varying degrees of success for protoplast isola-

tion: mechanical methods and enzymatic methods. Mechanical methods have been relatively complicated and quite time-consuming and therefore are not used to any great extent in modern protoplast culture. However, historically, mechanical methodology was the first technique used for obtaining satisfactory protoplasts for culture. Before 1960, mechanical methods were the simplest and most commonly used. The tissues were first incubated in a hypertonic solution leading to plasmolysis (shrinking of the cells from the cell wall). Protoplasts became spherical in shape when they shrunk from the cell wall, and then when the tissues were cut with a scalpel or sharp razor blade the protoplasts were released. A mini-pipet was utilized to collect the undamaged protoplasts under a microscope. This series of steps was called the micro-surgical process (16,37). Large amounts of protoplasts were damaged during the cutting and collecting but the techniques are reported to be successful using parenchyma or epidermal cells (6,37).

Enzymatic Method. After 1960, Cocking (9) introduced the enzymatic method using crude fungal cellulase, an enzyme which dissolves cell walls. Purified cellulase became commercially available after 1968 which stimulated much research in protoplast culture. A relatively large amount of protoplasts can be obtained from a small amount of plant material in a short period of time using the purified enzymes. A million protoplasts can be readily obtained from 1 gr of leaf tissue (10,11,21). The enzymes can harm protoplasts but cleaning the protoplasts several times with washing solution solves this problem (10,27). The enzymes, cellulase and pectinase, can be used separately or in combination (8,9,10,11). Successful enzymatic isolation is dependent on several factors, including use of an osmotic stabilizer, the right combination of enzymes, or suitable sequential timing of incubation, and the right kinds of enzymes (10,11). Cocking (9,13) has pointed out that the level of osmotic stabilizer has to be high enough to prevent the majority of protoplasts from bursting once the cell wall is weakened and yet not be so high that irreversible damage is done to the protoplasts.

It is apparent that the cells have to be plasmolyzed in early stages of enzymatic digestion. Several researchers have reported successful protoplast isolation by using high concentrations of osmotic stabilizer (13,21,28). Tribe (35) reported that the possible damaging effects to the protoplasts associated with enzyme incubation may be reduced if the cells are plasmolyzed but the cell functions may be adversely influenced (18). Shepard (29), showed that a large quantity of tobacco leaf protoplasts could be isolated under low osmotic stabilizer (0.25 M sucrose). Thus, the osmotic stabilizer appears to be very important for good protoplast isolation.

In our preliminar work on dahlia, the ray flowers and leaves were cut into small strips (0.5-1 mm), placed in solutions containing 0.1% macerozyme R-10), 0.4% cellulase R-10[3] and 0.30, 0.35 or 0.7 M D-mannitol, and incubated for 18 to 21 hours in the dark at room temperature. The osmotic value of the tissue was found to be approximately 0.36 M. We were able to obtain large amounts of good protoplasts in 0.35 M solutions (isotonic) while bursting protoplasts were observed in 0.30 M solutions (hypotonic) and abnormal conditions (systrophae) were observed in 0.7 M solutions (hypertonic). These results would corroborate the belief that for isolation of adequate numbers of good protoplasts it is important to have the osmotic stabilizer at the proper level.

The kind of osmotic stabilizer is also important. Mannitol, sorbitol (10,17), sucrose (28,29), and polyethylene glycol (10,36) have been used successfully. Mannitol is suitable because it is not readily metabolized or taken into the cytoplasm (13,14) while sorbitol is more soluble. Sucrose has been used, but it is difficult to filter sterilize and can be detrimental to protoplasts if used in high concentrations (13,14). The osmotic level and kind of osmotic stabilizer are important not only in isolation but also in culturing the protoplasts. Wallin and Erikkson (38) have shown that the osmotic pressure of the culture medium is of great importance for a good yield of dividing and growing protoplasts. For example, sorbitol at 0.2 M was the optimum concentration for carrot protoplasts to grow and divide while sorbitol at 0.5 M or higher inhibited protoplast division. Sucrose inhibited carrot protoplast growth and division in parallel experiments, indicating the importance of the kind of osmoticum used.

Our current research involves attempting to study the relationship between osmotic level of the isolation solution and the culturing solution together with the osmotic ground value of the tissues which are being used. We also anticipate using this technique as a possible tool for separation of chimeras, since plantlets derived from protoplasts should be individuals representing different characteristics, depending upon from what part of the plant the protoplasts were extracted. This could result in obtaining many totally new kinds of plants.

Freesias. In Europe, freesias rank 4th among all cut flower sales. They are normally propagated by corms and by separating cormlets from the mother corm. Propagating freesia by natural corm multiplication is relatively slow and it was considered appropriate to pursue tissue culture methods to hasten multip-

[3] Macerozyme R-10 and cellulase R-10 from Kinki Yakult Mfg. Co., Ltd. 8-21 Shingikan-cho, Nishinomiya, Japan.

lication. Most freesia organs are capable of regenerating roots and shoots (1); organogenesis was dependent on at least three factors: cultivar, light and dark, and auxin to cytokinin ratio (26). Tissue culture techniques show promise of producing a large number of plants in a short time. However, it has taken 16 weeks to produce plantlets (26) which is not as efficient as desired for commercial production. We have attempted to reduce the time of propagation and using aerial and basal corms.

Aerial corms were sterilized in 95% ETOH for 2 minutes and then in 0.5% NaOCl — Tween 20, rinsed 3 times with sterilized deionized distilled water and sectioned transversely into thin pieces about 1 to 2 mm thick. Three sections were randomly transferred onto 50 ml MMS medium as described previously for asparagus tissue culture. NAA and kinetin levels were employed at 0, 0.05, 0.1 and 1 mg/l respectively. The tissues were incubated in growth chambers at 25°C and with no light. Roots and shoots were both formed within 4 weeks of incumbation (Figure 3). NAA at 0.05 to 0.10 mg/l combined with kinetin at 0.05 mg/l promoted roots, while combinations of NAA at 0.1 mg/l with kinetin at 0.05 mg/l was the best balanced medium for shoot and root formation. Higher NAA (1 mg/l) or kinetin at 5 mg/l promoted callus formation but few roots and shoots.

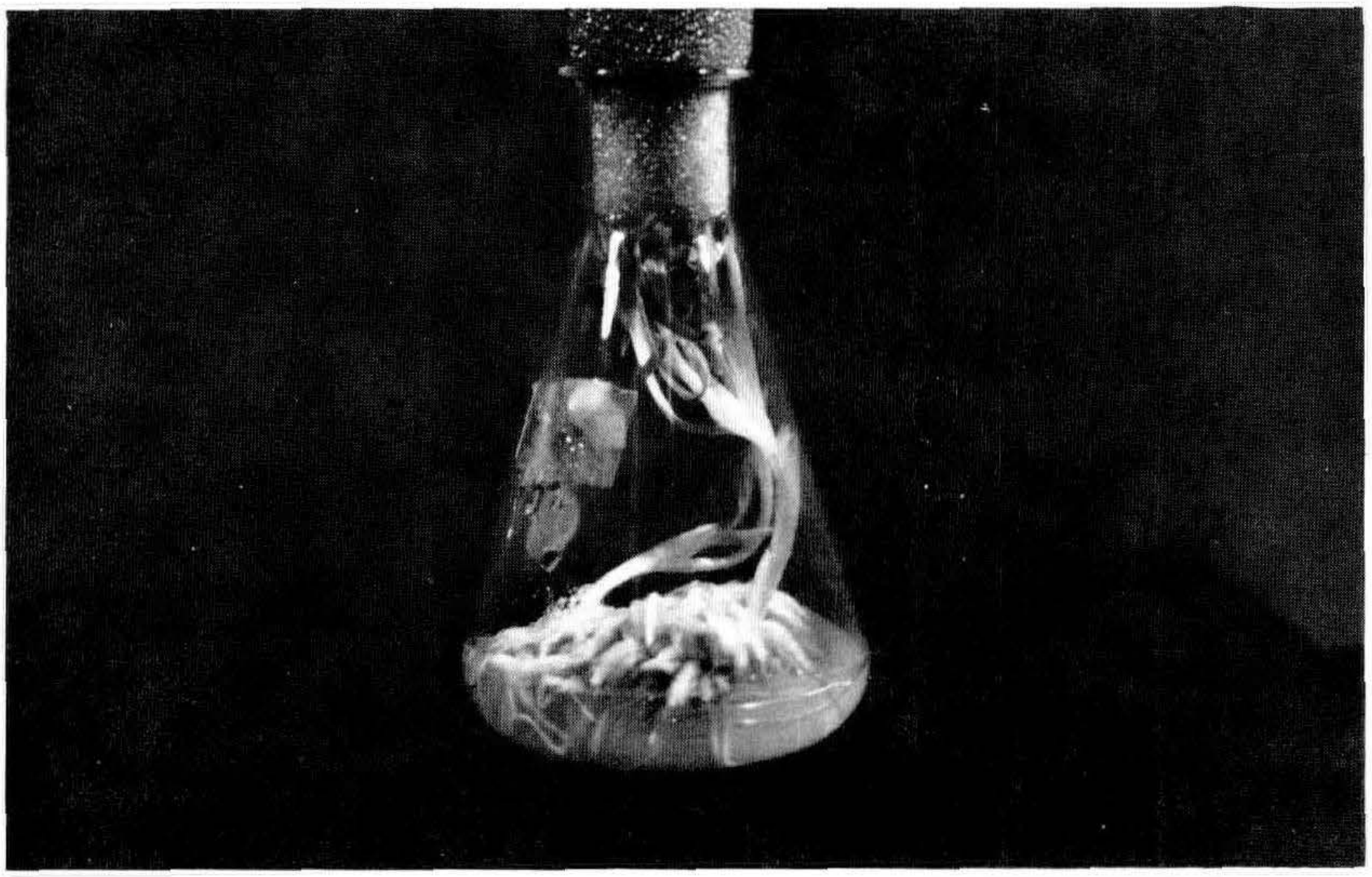

Figure 3. Plantlets of freesia derived from pieces of aerial corms.

After shoots and roots were formed they were incubated 1 to 2 weeks under cool white flurorescent lights of 16-hour duration and 100 ft-c intensity. The plantlets were transplanted to moist peat and placed under cool white fluorescent lights at room temperature. Success of transplanting was dependent on

plants having root to shoot vascular connections. They were then watered with MMS nutrient solution. Tap water was used after the first week. Plants were transplanted to soil and placed in the greenhouse within 7 to 8 weeks after transferring. By this method of transplanting, plants from the flask could be established in the greenhouse 10 to 12 weeks after culture was begun. This represents a reduction of 4 to 6 weeks when compared to published work on freesia tissue culture (26).

We plan to continue research in the areas described, in an effort to improve propagation time, efficiency and to perhaps develop potential new clones.

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CELL-FUSION HYBRIDS

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Abstract. Cell-fusion hybrids were obtained by fusing protoplasts of *Nicotiana glauca* and *N. langsdorffii* in the presence of polyethylene glycol. The hybrid protoplasts were selected out of a mixed population by growing on a culture medium that does not support the growth of parental protoplasts. The cell fusion hybrids had chromosome numbers that were higher (56 to 64) than in the amphiploid (2n = 42). Most of these "hyper-aneuploids" were fertile and their progeny retained the characteristic morphology and approximate chromosome number of their hybrid parent.

The technical advance of being able to remove plant cell walls in order to produce viable wall-less or naked cells (the protoplasts) has opened up new avenues of research in plant propagation and improvement. These fall into two main categories of use: 1) fusion of protoplasts to give hybrid somatic cells, thus by-passing the usual sexual techniques of hybridization by cross-pollination; 2) facilitated entry or more rapid uptake of "genetically informed" particles that are generally excluded by the cell wall; for example, foreign macromolecules (DNA and RNA), chromosomes, nuclei, organelles and viruses. The genetic significance in all these cases is that new additional genetic material migrates into the protoplasts and, in so far as it persists through replication and integration, adds significantly to the genetic variability (8).

The successful production of cell-fusion hybrids has been greatly aided by two additional new techniques for handling protoplasts. These are: 1) the use of polyethylene glycol (PEG) to adhere and fuse protoplasts; and 2) the development of selection methods to recover preferentially regenerated fused hybrid protoplasts from a mixed population of protoplasts.

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MATERIALS AND METHODS

The method that we follow to produce fusion hybrids of *Nicotiana* species is outlined below.

1) Pick young leaves from vigorous half-grown plants and surface sterilize them by spraying with 60% ethanol. This, and all subsequent manipulations, are carried out under aseptic conditions in a transfer room or hood.

2) Strip the epidermis from the lower surface of a leaf, slice the epidermis-free areas into strips, and place them into a 1:1 mixture of E1 and M3 solutions. See Kao, *et al.* (4) for preparation of solutions. The E1 solution contains 2% cellulase, 2% hemicellulase and 1% pectinase. The M3 solution is a rich nutrient medium for culturing plant cells. Leave the leaf strips in the solution mixture long enough to give a good yield of protoplasts. This takes 3 or 4 hours at room temperature (about 23°C) with favorable material, as most Solanaceae.

3) Harvest the protoplasts by filtering through two layers of miracloth, which gives an effective mesh of about 50μ, into a centrifuge tube. The two sources of protoplasts, that are eventually to be fused, can be collected into the same centrifuge tube at this time.

4) Wash the protoplast preparation free of enzymes by gradually eluting the solution mixture and replacing it first with pure M3 solution and finally with two washings of solution D of Kao *et al.* (4).

5) Preparatory to fusion, pipette a large drop ($\pm$ 150 μl) of a concentrated suspension of the mixed protoplasts onto a 22 $\times$ 22 mm cover slip that has been adhered to the bottom of a 60 $\times$ 15 mm plastic petri dish, see Smith *et al.* (10). After the protoplasts have settled onto the cover slip (ca 5 min), slowly add 450μl of PEG solution to the protoplast culture. The composition of this solution is PEG 1540 (0.33M), $CaCl_2 \cdot 2H_2O$ (10.5 mM), and $KH_2(PO_4) \cdot H_20$ (0.7mM). Adhesions of membranes begins immediately.

6) Incubate the protoplasts in the PEG solution for about 30 minutes.

7) Gradually elute the PEG from the suspension by repeated washing with M3 solution.

8) Maintain the culture of fused protoplasts under conditions of low light (50 to 100 lux), 23°C and a minimum of vibration. Add more M3 culture medium as cell divisions begin and colonies are formed (in 4 to 5 days).

9) When the colonies reach 2 to 3 mm in diameter (in 4 to 5 weeks) transfer to an agar (0.8 percent) solified medium that has the same sucrose, mineral salt and iron composition as the

Murashige-Skoog formulation (6), the vitamin content of B5 medium (2), and no phytohormones. In our experiemnts with fusing protoplasts of *Nicotiana glauca* and *N. langsdorffii* the absence of phytohormones in the medium selects against the parental species cells and favors the growth of the hybrids, which have less stringent cultural requirements. It is important to initiate some kind of selection system to aid in picking out the hetero-fusion products as early as possible. Others (3,5) have used photosynthesis-deficient complementary markers, to define and eliminate the parental cells and homospecific fusion products.

10) When the calli have reached the size of a small pea, place them on a medium and under conditions that favor differentiation. With our *Nicotiana* material these are a temperature of 25°C, 16 hours of light at ±5000 lux to 8 hours darkness, and a culture medium that contains Murashige-Skoog (6) major and minor salts, 30 g/l sucrose, 27.8 mg/l iron, and no vitamines, glycine, inositol, or hormones. These calli that originated from protoplasts are no different from cultures derived from walled cells or masses of tissue. Extensive reviews and a manual on methods for culturing plant cells and tissues have been compiled recently by Street (11) and by Gamborg and Wetter (2).

Our *N. glauca* + *N. langsdorffii* calli differentiate leaves and shoots more readily than roots. Those without roots were grafted onto plants of either parent as stock (Figure 1). Those with roots were transplated directly into soil in pots and were maintained in a high humidity section of the greenhouse until established. These methods of culture gave mature parasexual hybrids that flowered in about 7 months after protoplast fusion (10).

Figure 1. Teratological scion grown from a differentiated rootless callus of a parasexual hybrid (*Nicotiana glauca* + N. langsdorffii) and grafted onto a stock of *N. langsdorffii*.

All the parasexual hybrids were self-pollinated and most produced seeds. Mature plant progenies have been obtained from these fertile parasexual hybrids (9), which were more frequently derived from rooted calli than from grafted scions.

RESULTS

Cytogenetic analyses of 13 of the parasexual hybrids produced by fusing protoplasts of *Nicotiana glauca* and *N. langsdorffii* are shown in Table 1 along with observations on their progeny.

Table 1. Cytogenetictic analysis of 13 fertile parasexual hybrids (*N. glauca* + *N. langsdorffii*) and their progeny.

Parasexual Hybrids					Progeny		
Callus No.	Propagation	Somat. chrom. No.	No. bivalents	Pollen fert. %	No. pls.	Somat. chrom. No.	Pollen fert. %
7-2	root cal.	62	30	88.6	20	59	90.3
11-5	graft	56	26	85.1	21	54	88.8
23-2	root cal.	60	28	87.7	28	62	83.2
30-8	root cal.	64	32	82.7	23	61	89.0
31-6	root cal.	60	30	86.9	39	59.2	84.9
35-1	root cal.	58	28	86.1	37	59.5	90.4
35-6-1	root cal.	63	30	83.7	40	57	88.6
35-6-2	root cal.	60	27	89.2	2	58	79.3
41-6	root cal.	58	28	80.3	20	60	81.9
46-4-1	root cal.	60	30	90.9	8	60	92.7
46-6	root cal.	58	29	73.5	54	54	65.2
47-1	root cal.	60	30	82.7	29	60	88.4
51-6	root cal.	63	29	93.4	31	62	89.4
Mean		60.2	29.0	85.4	27.1	58.9	85.5

The chromosome numbers in the parasexual hybrids ranged from 56 to 64, averaging 60. The most common number of bivalents found in the first meiotic metaphase was 29, an unexpectedly high frequency. This high degree of meiotic regularity gave a high pollen fertility, averaging 85%. The plants were verified as hybrids based on: 1) requirements for tissue culture; 2) morphological characteristics of the leaf (Figure 2); 3) morphological characteristics of the flower (Figure 3); 4) spontaneous tumor formation on aging (7); and 5) general growth habit (10)

The progeny of the parasexual hybrids (Table 1) ranged in chromosome number from 54 to 62 with an average of 59, which is similar to that of their parental hybrids. The plant progeny of any one parasexual hybrid was relatively uniform in leaf and flower and tended to be similar to its parasexual hybrid parent which, in turn, was similar to the sexually-produced amphiploid between *N. glauca* and *N. langsdorffii*.

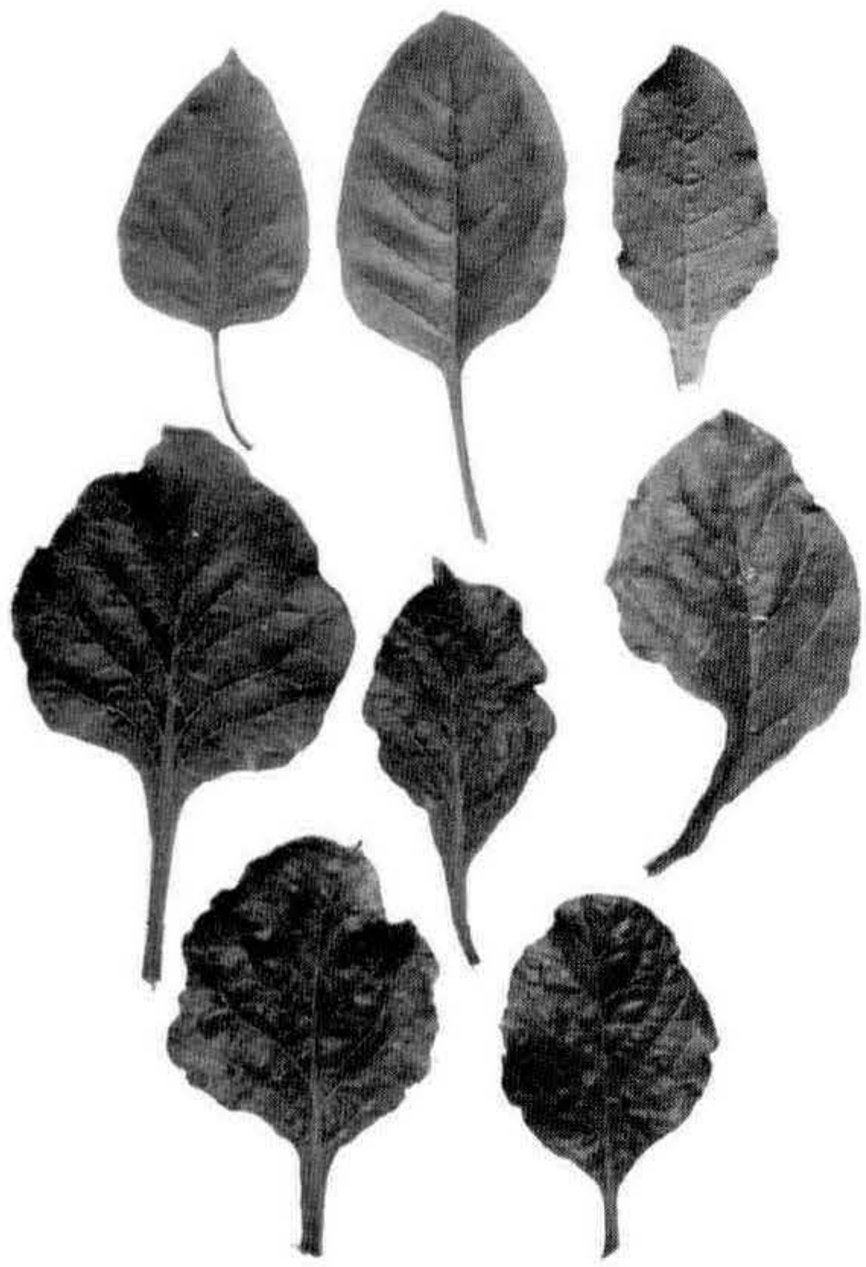

Figure 2. Leaves of *N. glauca*, the amphiploid and *N. langsdorffii* (top row, left to right); and five different parasexual hybrids (below). The cell fusion hybrids show features in common with the amphiploid, but they differ from it and from each other due to their various aneuploid chromosome numbers.

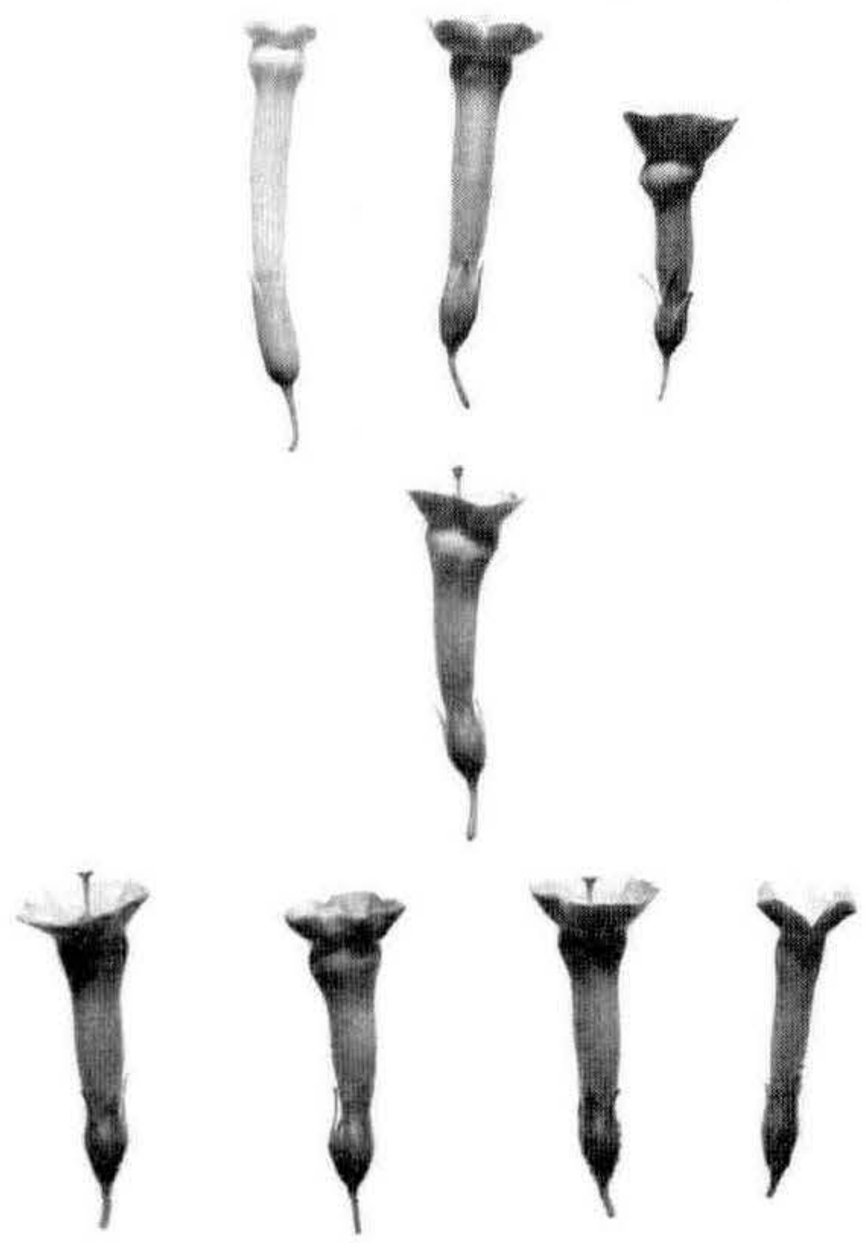

Figure 3. Flowers of *N. glauca*, the amphiploid, and *N. langsdorffii* (top row, left to right); a parasexual hybrid (center) and four progeny of the parasexual hybrid (bottom row).

DISCUSSION

These methods and the hybrids obtained with them have fully confirmed and have extended the results of earlier experiments (1), namely that: 1) parasexual hybrid cells can be produced by fusing somatic protoplasts of *Nicotiana glauca* with *N. langsdorffii*; 2) the hybrid cells can be selected out of a mixed population on the basis of differential growth in specifically defined culture media; and 3) the hybrids can be grown to maturity, are often fertile, and produce abundant progeny.

Although this experimental material serves primarily as a model system to demonstrate parasexual hybridization, its success depends on applying selection based on differential growth of parents and hybrid in a specific culture medium; and an extension of this general principle to other materials may ultimately prove its wider application. For example, the ubiquitous phenomenon of interspecific hybrid vigor, if expressed in more rapid callus growth, might be used to select parasexually produced hybrids from a mixed population containing parental calli.

The chromosome numbers found in the parasexual hybrids were unexpectedly high since a simple addition of the two parental species numbers would give 42; i.e. *N. glauca* = 24 and *N. langsdorffii* = 18. The departures from this number could be attributable to serveral causes e.g.: 1) a different abnormal chromosome number present in source leaf cells of the parental species; 2) multiple protoplast fusion, or 3) unequal mitoses occurring during growth from protoplasts to callus to differentiated plant. The specific range found, i.e. from 56 to 64 chromosomes suggests that triple fusions may have occurred (18 + 24 + 18 = 60, 18 + 24 + 24 = 66), that there was some loss of chromosomes in subsequent mitotic divisions, and that the particular aneuploid types recovered were those that were more successful than others in yielding viable cultures capable of differentiation into mature plants. This phenomenon might find use in genetic and breeding experiments for, instead of producing a single true-breeding amphiploid, a highly variable population of new (mostly fertile) interspecific combinations are found.

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SOME POTENTIALS OF PLANT CELL AND TISSUE CULTURE

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Plant tissue and cell culture techniques have advanced to the stage where their application to commercial plant propagation is imminent, and in quite a number of cases, is in actual practice. The purpose of this paper is to review some of these techniques and point out their potential practical value for plant propagators and others. These techniques include opportunities for: 1) rapid plant multiplication; 2) eradication of viruses and other tissue-borne pathogens from "old" cultivars; 3) production of homozygous lines; 4) long-time storage of germplasm; 5) transfer of genetic information with isolated DNA, and 6) more efficient plant breeding. Somatic hybridization of protoplasts to develop parasexual plant hybrids has been discussed by Dr. Smith, and the use of shoot-tip culture for plant propagation has been covered by Mark Cunningham.

RAPID MULTIPLICATION OF PLANTS

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mums, tissue culture of shoot-tips is being used to multiply orchids and Boston ferns. It has been reported that one American nursery is producing over 50 to 100,000 plants of Boston ferns each month from tissue cultures. Bulb crops, such as hyacinths, lilies, and narcissus, are especially amenable to propagation in large numbers by these methods. Researchers in Florida are using this method for the rapid propagation of pathogen-free clones of aroid crops such as caladiums and taro. Though far from perfect, these methods are bases for the potential use of tissue culture in propagation of many plants in almost infinite numbers.

ERADICATION OF PLANT PATHOGENS FROM "OLD" CULTIVARS

Plants which must be propagated from vegetative tissues often become infested with pathogens. Once infested, further propagation of the plant frequently propagates the pathogen, along with the plant, particularly in the cases of viruses. Fortunately, the growing tips of most plants are free of pathogens. Hence, if one cultures extremely small meristem tips, usually 1 mm in size, plant tissue cultures can be obtained which are free of the pathogens or which can be freed from pathogens. Once such pathogen-free tissue cultures are obtained, all succeeding plants derived from such cultures are likewise pathogen-free. By such means, viruses have been eradicated from plants, such as garlic, for which no virus-free material was previously known anywhere in the world. Because garlic never produces true seed, no method was known to develop virus-free stock (before the advent of tissue culture methods). Poplar trees freed from virus grow 10 to 30% faster than virus-infected poplars.

International plant introduction stations can control and eliminate viruses and pathogens more easily in tissue culture.

Likewise, the old potato cultivar 'Irish Cobbler' developed 150 years ago, was universally infested with virus X. Today, as a result of meristem tip cultures, virus-free 'Irish Cobbler' has been developed. Such virus-free clones most commonly yield 15 to 20% more than the usual clones.

Thus, today, using tissue culture methods, viruses and other disease organisms may be eradicated from horticultural cultivars which are universally infested. These techniques are now being used for developing disease-free cultivars of potatoes, dahlias, geraniums, gladiolas, and tree species.

PRODUCTION OF PLANTS THAT BREED TRUE FROM SEED

Most woody plants and trees are extremely variable when grown from true seed. From the standpoint of most nurserymen,

this lack of uniformity is undesirable and is usually overcome by the more expensive method of vegetative propagation.

However, true breeding clones of plants may be developed by using the method of culture of pollen grains or unfertilized ovules. Tissues from pollen grains or ovules, when their chromosome complement is restored to the same number as the original parent plant, are homozygous or true breeding. Progeny grown from seed of such plants would be essentially comparable in uniformity to vegetatively propagated plants. This method appears especially desirable to produce true breeding plants such as trees that require many years between generations.

Although this method of producing true breeding plants has great potential, this technique cannot be applied today for most nursery crops. At present, unfortunately, the primary drawback is that tissue cultures of most woody plants will not easily regenerate into plantlets. Until this bottleneck is overcome, we cannot widely use this technique to develop true breeding woody shrubs — but that day is fast approaching.

LONG-TIME STORAGE OF PLANT TISSUES UNDER LIQUID NITROGEN

Of particular importance to horticulture is the potential for storage of vegetative material by tissue culture methods. For example, carrot tissue has been placed in tissue culture, frozen, stored in liquid nitrogen, thawed 2 years later, and used to regenerate normal carrot plants. This technique has also been used on morning glory, sycamore, and a few other plants.

This method could be effectively used to provide germplasm banks for collection of potatoes, fruit trees, and woody plants which now must be maintained by methods of vegetative propagation that are highly expensive and risky from the standpoint of diseases. Cryogenic techniques to store plant cells, including pollen, microspores, anthers, and ovaries have great potential. World genetic sources are disappearing rapidly. Unless they are protected, cultured, or stored, they may disappear forever.

TRANSFER OF GENETIC EFFECTS BY ISOLATED GENES OR FRAGMENTS OF DNA

The use of tissue culture methods for transfer of genetic potential among similar plant species and among widely divergent plant species is producing practical results. As one example, Dr. F.B. Holl of the National Research Council of Canada transferred the potential to fix atmospheric nitrogen from 'Trapper' pea (*Pisum sativum* L.) to 'Afghanistan', a pea cultivar that normally lacks nitrogen-fixing capabilities.

Gene transformation is accomplished by extracting DNA from a donor plant and "feeding" it to a receptor plant. Directed higher plant modification, in much the same manner that has been done for several years with bacteria, is an exciting potential. Many valuable plant characteristics that are selected for by nurserymen have a biochemical-genetic basis that conceivably could be transmitted from donor plants to recipient plants, thereby circumventing the conventional methods of plant breeding.

PLANT BREEDING

Plant breeding by today's conventional means is relatively slow and expensive. I am convinced that plant tissue culture methods now being developed will enable plant breeders of the future to accomplish as much in the space of a small room as now requires huge field acreage. The desired results will be accomplished in a small fraction of the time now required. A flask developed by shaker culture of plant tissue contains many millions of cells, *each cell* having the potential of a full grown plant. By subjecting such flasks of cells to appropriate selection pressures, plants could be selected for the desired character from a random population composed of millions of potential plants. The highly successful techniques hitherto available only to bacterial genetics are now potentially applicable to all higher plants.

Today, somatic mutations in plants are rare. They are rare because *only* the mutations which occur in one cell, the *apical* cell, can be expressed. Mutations occurring in the billions of other cells making up the plant parts are not expressed in normal plant growth. With tissue culture methods, this "locked up" variability in the somatic cells is freed and may be readily expressed. The potentials of such unlocked variability in plant improvement go beyond our imagination. These potentials will be achieved in the near future. They await only the day when we can achieve the goal of growing a full-grown plant from any cell in tissue culture, a goal which today has been achieved with relatively few plants.

In summary, these exciting developments and remarkable breakthroughs in plant cell and tissue culture offer new opportunities and new horizons for those who possess the foresight to capitalize on them. We must aggressively seek out and purposefully use these new methods, new ideas, and new products of research.

PROPAGATION OF SOME HAMAMELIDACEAE (WITCH-HAZEL FAMILY)

ALFRED J. FORDHAM

Arnold Arboretum, Harvard University
Jamaica Plain, Massachusetts

PROPAGATION OF HAMAMELIS (WITCH HAZEL)

In August, 1973, I was part of the delegation of I.P.P.S. members from the United States that attended the Sixth Annual Meeting of the I.P.P.S. Region of Great Britain and Ireland. During the technical sessions held at Berkshire College of Education, G.V. Purcell of L.R. Russell, Ltd., Windlesham, Surrey, presented a paper pertaining to the budding of *Hamamelis*. In the discussion that followed we learned that in Britain propagation is by budding and grafting, using *Hamamelis virginiana* as understock. We also learned that seeds and seedlings are becoming unavailable in Britain and there was much concern about the future propagation of *Hamamelis*. Actually there is no problem, for experience at the Arnold Arboretum with 22 taxa indicates that all *Hamamelis* can be rooted from cuttings which can then be induced to survive the first winter.

In recent years many new cultivars of *Hamamelis* selected and named in Europe have been imported by the Arnold Arboretum. They were grafted plants, and shoots arising from understocks were a nuisance. It is not uncommon to see plants where the understock is taking over. Therefore, whenever we receive grafted plants they are propagated by cuttings at the earliest opportunity.

Collection of Seeds. Fruit capsules of *Hamamelis* are ready for collection toward the end of August in the Boston area. At this time the capsules are still soft and green, but the seeds within have developed hard shiny coats and are mature. Harvesting can continue until about the time the plants shed their leaves. The fruit consists of capsules, each of which contains two hard, shiny seeds. As the capsules dry they shrink and bring pressure to bear on the seeds within. Finally, with a sharp snapping sound the seeds are ejected with enough force to drive them surprising distances. To test the distance travelled, some branches bearing capsules were placed in a large room where flight of the seeds was unimpeded. Height from the floor was 4 feet. Many of the seeds were flung over 20, and one travelled 32 feet. By this means the seeds are propelled away and removed from competition with the parent plant.

After collection, the capsules are placed in a warm dry location where in a few days the seeds will have popped and can be separated from the capsules by screening. The capsules must

be contained in some way, for if not confined the seeds will be strewn all over the area as they are dispelled. A paper bag fastened at the mouth with a paper clip is satisfactory for small quantities.

Treatment of Seeds. Seeds of *Hamamelis japonica,* H. *mollis,* and *H. virginiana* have proven to be doubly dormant (two-year seeds). To be prepared for germination they require warm fluctuating temperatures followed by a period of cold. Pretreatment may be done in polyethylene plastic bags which have the property of being air-permeable yet water-proof, making them ideal for seed stratification.

The stratification medium can be composed of half sand and half peat moss mixed together and dampened. I emphasize the word "dampened", for a wet, soggy medium could exclude sufficient oxygen. In proportion the medium should be two or three times the volume of seeds. The proportion is important because at sowing time the entire contents of the bag are sown. The seeds are combined with the medium and the mixture is placed in the polyethylene bag, which is then bound at the mouth with a rubber band, making it water-proof.

For the warm period of stratification the unit is placed in a location such as a greenhouse bench where the day and night temperature will fluctuate. Direct sun should be avoided, for it could lead to a detrimental build-up of heat. The three species of *Hamamelis listed above have responded well* to exceptionally long periods of warm stratification. Twelve months of warm pretreatment followed by 3 months in a 40°F refrigerator led to a high percentage of germination in 2 weeks. An alternative procedure to prepare these seeds would be to sow them out-of-doors and let seasonal changes satisfy the requirements. *Hamamelis vernalis* germinated about as well after cold stratification only, as it did after two stages of pretreatment.

Propagation by Cuttings. There is a wide latitude in the time suitable for taking *Hamamelis* cuttings. Softwood cuttings collected in the latter half of June and cuttings of semi-ripe wood gathered throughout the month of July have all rooted in high percentages.

Cuttings can be treated with any of the several root-inducing formulations containing IBA at the rate of 8 mg in a gram of talc. We have been using one which contains this plus the fungicide Thiram at the rate of 15%. The cuttings are made in the usual manner, set in plastic trays and placed under intermittent mist. Wounding the cuttings on one side was tried and discontinued — it showed no advantage, as the roots arose only from the bases of the cuttings. A rooting medium composed of sand and perlite in equal parts has proven satisfactory.

Cuttings handled this way should be well-rooted in about 5 weeks.

First Winter Survival. Some plants that are propagated from softwood cuttings during summer present a survival problem during the following winter. They go into dormancies from which they never recover. Among these are the various taxa of *Hamamelis*. One means of overcoming the problem is to induce the newly-rooted cuttings to make new growth by providing supplementary lighting. First-winter loss can also be averted if the cuttings are not disturbed after they have rooted. To accomplish this the cuttings are rooted in plastic flats under mist as described above. When rooting has taken place the cuttings are left undisturbed in the flats and hardened off under polyethylene plastic. Work at an Arboretum involves handling a large diversity of taxa but small numbers of each. Cuttings are started at varying times and some root sooner than others. This makes it impractical to use a weaning procedure after cuttings have rooted. Therefore they are removed from under mist and placed under polyethylene for hardening off. In autumn the trays of undisturbed cuttings are drenched with a combination of Dexon and Terrachlor before being transferred to a cold-storage unit. Here the temperature is maintained at approximately 34°F. In about 3 months the trays are returned to a warm greenhouse where new growth soon appears. The time of return to the greenhouse is based on convenience to the work program rather than on a specific schedule. As soon as they start to grow the cuttings are transferred. Those to be planted out in spring are moved to peat pots, and those to be grown in the can section are placed in containers.

PROPAGATION OF FOTHERGILLA (WITCH ALDER)

Collection of Seeds. In the Boston area fruit capsules of *Fothergilla* are ready for collection in late August. At this time the still green capsules contain fully developed seeds. The seeds are dispersed by propulsion as described for *Hamamelis*. Scattering commences about mid-October and will be completed in a few days if the weather is dry.

Treatment of Seeds. Seeds of both *Fothergilla major* and *F. gardenii* have proven to be doubly dormant and pretreatment must be done in two stages. *Fothergilla major* seeds have germinated in high percentages after 12 months of warm stratification followed by 3 months at 40°F. *Fothergilla gardenii* responded well to 6 months warm pretreatment and 3 months at 40°F.

Grafting. Fothergilla species can be propagated by grafting, using established understocks of *Hamamelis virginiana*. But

grafting of *Fothergilla* is unjustified for as with Hamamelis, shoots arising from understocks can create a nuisance.

Cuttings. Both species of *Fothergilla* root well from softwood cuttings. Time of collection, cutting preparation, time of rooting and winter survival procedures parallel those of *Hamamelis*.

PROPAGATION OF LIQUIDAMBAR STYRACIFLUA (SWEET-GUM)

Collection of Seeds. The round spiny, aggregate fruit heads of *Liquidambar styraciflua* must be collected before dehiscence occurs or the winged seeds will be lost to dispersal by wind. Ripeness of the seeds is indicate by color change of the fruits which pass from green to yellow. In the Boston area this occurs about the first of October.

When provided with a warm dry location, the fruits will open to release the seeds in a week or two. Relative size of fruits and seeds makes cleaning by two screenings a simple process. First, the fruit heads are bounced in a screen of about 1/2 inch mesh. This completes the extraction and separates the sound and abortive seeds from the fruits. Second, a screen with 10 squares to the inch will retain the sound seeds but allow the small abortive seeds, which are always present, in large amounts, to pass through.

Seed Germination. Seeds of *Liquidambar styraciflua* exhibit dormancy that can be overcome by cold stratification. Seeds to be sown out-of-doors in spring can be stored until time for stratification. Either 2 or 3 months prior to sowing, the seeds are stratified as described for *Hamamelis*.

When seeds are processed in a greenhouse the same course of action would be followed but with the stratification period planned so the seedlings would grow during the lengthening days of late winter. When treated by this method, using either a 2 or 3 months stratification period, a general germination can be expected in about 18 days. *Liquidambar syraciflua* has an unusually wide geographical distribution. From northern limits in Connecticut and Illinois it grows southward to central Florida and eastern Texas. Isolated populations are found in Mexico, Guatemala, Salvador, Honduras and Nicaragua. Therefore, the recommendation given here would only apply to seeds from trees of northern origin.

Cuttings. *Liquidambar styraciflua* have rooted in high percentages when cuttings were made in early July using half-ripe summer wood.

Bud Grafting. *Liquidambar styraciflua* bud-grafts readily.

Cultivars may be propagated by this method using seedlings of the species as understock.

PROPAGATION OF PARROTIOPSIS JACQUEMONTIANA

Seeds. Following the procedures for *Hamamelis*, seeds of *Parrotiopsis* germinated when provided with 5 months of warm stratification followed by 3 months at 40°F.

Cuttings. Greenwood cuttings taken in mid-July and treated with 8 mg of IBA in a gram of talc rooted 100% in two instances.

PROPAGATION OF SINOWILSONIA HENRYI

Seeds. Three months of cold stratification at 40° led to a uniform stand of seedlings in 14 days.

Cuttings. Greenwood cuttings treated with IBA plus NAA at the rate of 2500 ppm each led to 80% rooting, and first winter survival when they were processed as described for *Hamamelis*.

PROPAGATION OF PARROTIA PERSICA

Cuttings. Softwood cuttings taken in late June were divided into two batches. Each was treated with a formulation containing IBA in talc. Lot #1 at the rate of 3 mg per gram and Lot #2 at 8 mg. One hundred percent rooting took place in each lot.

Grafting. In commercial practice *Parrottia* is grafted, using *Hamamelis virginiana* seedlings as understock.

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RHODODENDRON PRODUCTION

TED RICHARDSON

Rhododendron Farm
Mountain Home, North Carolina

Rhododendron Farm is a small family operated nursery. The husband and wife owners started producing rhododendrons in 1963. The original unit was a greenhouse liner operation. In 1968 this was sold and container growing of larger plants was taken up. About 2½ acres are utilized in Mountain Home, N.C. for finishing off 3 gal plants. The greenhouse liner production was replaced with an out-of-door operation in southern Florida utilizing about 1/2 acre. Attempts to maximize growth have resulted in the production of many cultivars of hybrid rhododendrons to a 15″ to 18″ size in 15 months from the time the cuttings are taken from the stock plant, and 24″ to 30″ plants in 27 months. The owners have performed all laborious jobs, except occasional day labor for potting and loading and unloading, until 8 months ago when one skilled person was hired full time to share in the confinement and the long hours require of the business.

Climate. Mountain Home is located near Asheville, N.C., in the Blue Ridge Mountains at an elevation of 2100 feet. Winter temperature seldom goes below +12°F and many nights remain above 32°F. The extreme at the nursery has been -8°F. Ground thawing occurs almost every day so there is seldom any build up of frost in the soil. There are sometimes prolonged warm periods — when the plants become active — followed by sudden hard freezes. Frosts occur as late as May 19 and as early as October 1. Extreme summer temperature does go up to 95°F but rapid cooling almost always follows sunset. Night temperatures usually drop to the high fifties in middle sixties giving a low average daily temperature. At the Florida location, winters are quite like the springs at the North Carolina location. In the past 5 years there has been only one minor frost.

Propagation. A stock block is maintained from which about 75% of the cuttings are taken. The remainder come from production stock in the nursery. Current season's growth is taken just as soon as it hardens. This is very important as in a very few days the buds on these shoots begin to grow into a second flush. Then propagation would have to be delayed until fall. The removal of the cuttings begins around daybreak so as to harvest as many as possible while they are covered with dew and before turgor pressure within the leaf is reduced. Cuttings are stored in plastic bags and taken inside where leaf area is reduced and stem length cut to 2½ inches. A 5 minute soak in a

Malathion-Benlate solution follows. After excess water has dripped off, they are again stored in plastic bags until later in the day. They are then wounded on one side by the removal of a sliver of bark about 1½ inches long from the base of the stem. This portion of the stem is then coated with a film of Hormodin #3 powder and placed on 2 inch centers into a mixture of equal parts peat and perlite.

The rooting beds are designed for handling by forklift, stacking for transport, and for rapid drainage. They are 3 feet wide and 7 feet long. The bottom is made of galvanized wire mesh and is held off the floor by 4 × 4 inch runners. Fine mesh netting is placed over the wire to retain the medium. The beds are placed side against side and lined up in an open ended quonset greenhouse built under heavy shade of large oak trees. Sprinkling is through Buckner rotary sprinklers for 10 seconds at either 5 or 10 minute intervals depending on light intensity and humidity on any particular day. This is controlled manually by placing or removing a tripper on the timer.

Container Production. Cuttings usually root in 8 to 12 weeks. About the first of November they are loaded on a truck and taken to Florida where they are potted and grown through the winter. This step in production replaces the use of greenhouses in North Carolina. During the first week of May the containers are loaded on trailers and returned to North Carolina where growth continues through the summer. This results in five or six flushes of growth with flower buds forming on some cultivars.

White 3-gal plastic containers are used. Actual temperature data taken in 1972 showed the center of the root ball to be 10°F cooler in white than in black containers. There has been a problem with short life of white plastic but the manufacturer is now adding more ultraviolet light inhibitor and hopefully this will solve the problem. Pine bark with no additives is used as the sole container medium. This bark has particles ranging in size up to 3/8 inch and contains about 18% airspace. This has almost eliminated *Phytophthera* root rot and results in a 3-gal root ball 3 months after potting. Fertilizing is done daily through the irrigation system. Little attention is given to pH as this is no longer considered important by us in our system of production. We have had beautiful rhododendrons with a pH of 7.2. The fertilizer contains minor elements. The shaping of plants is accomplished by removal of the terminal buds from the first four flushes of growth. Cultivars which do not respond well to this treatment have been mostly discontinued. Containers are spaced on a gravel surface which has been treated with herbicide. An airblast sprayer is used bi-weekly to control insects and leaf attacking fungi.

Cultivar Selection. We currently list 40 cultivars of hybrid rhododendrons and this number gets smaller every year. While we have discarded over 200 cultivars, we still continue to search for new material and put it under trial in our environment. We find that generally those cultivars which are more cold hardy are also more heat tolerant. We do not have a breeding program but do have a number of selected seedlings obtained from other people.

Conclusion. We find this to be an efficient system of growing rhododendrons for our size of operation. There is no regular person at the Florida operation. A neighbor checks the pump daily to see that it functions properly. All other routine labor is performed on a bi-weekly commuting basis by one person. Since inventory turnover is rapid, less investment in physical facilities is needed. There is also considerable saving in fuel comparing that used for transportation with that which would be required for heating a 1/2 acre greenhouse.

Wednesday Evening, August 25, 1976

The twenty-sixth annual banquet was held in the Neilson Dining Hall of Cook College, Rutgers University, New Brunswick, New Jersey.

On behalf of the Society, Dr. Francis Gouin presented an award for the best student paper to Mr. Brian Dykeman. A separate award was presented to Dr. Harold Davidson as director of the work presented in the paper by Mr. Dykeman. Mr. Leonard Savella made the following presentation:

MR. SAVELLA: The nominee for the 1976 IPPS Eastern Region Award of Merit is a career nurseryman. He has been quite active serving on various committees within the Eastern Region, including the Executive Committee.

Because of these efforts, and his work as an Eastern Region president, the growth and development of this Region has been helped greatly. Our recipient has that rare quality of being an outstanding plant production-oriented person along with the attribute of being business-minded. Cost and cost production data have always been something of which he is keenly aware. He possesses that precious quality of seeking and sharing. The papers which he has presented to our Society plus those which have been printed in the various trade publications have assisted countless plant propagators. He also seeks information from his brother Society members to upgrade and improve his present production techniques. His concern for his fellowman exemplifies his deep Christian belief which is felt so keenly by

him. The constant effort to improve and to contribute are apparent to anyone who has worked with him. Ladies and gentlemen, it is a great honor for me to present the Eastern Region 1976 Award of Merit to the person who served as the Eastern Region President in 1970, Mr. Tom Pinney, Jr., Evergreen Nurseries, Sturgeon Bay, Wisconsin.

The banquet speaker was Mr. Phillip Alampi, Secretary of Agriculture for the State of New Jersey.

QUESTION BOX

The Question Box Session was convened at 8:15 p.m. immediately following the annual banquet. Mr. Ralph Shugert and Dr. William Snyder served as moderators.

MODERATOR SNYDER: Ben Davis, have you tried grafting peach cultivars onto *Prunus besseyi* or *P. tomentosa*?

BEN DAVIS: The paper I presented dealt with producing standard trees but we have used *P. besseyi* as a dwarfing rootstock. We have never tried grafting them; we T-bud them but when we used *P. tomentosa* we had very poor results so we now T-bud only on *P. besseyi*.

MODERATOR SNYDER: Were the bench grafts you made done by hand or machine?

BEN DAVIS: We bought one of those grafting machines and so we made them both ways; I had a count made but after looking at the figures I'm not sure they're correct. This year we made about 25% of our apple grafts on the machine and, as a rough figure, we got about 25 to 30% take as compared to 50 to 60% by hand grafting. We were saving $19/1000 grafts in labor costs by using the machine but when we only get 25% take this isn't very good.

MODERATOR SHUGERT: Harold Stoner, what is the cost of your finished sewage sludge compost per cubic yard?

HAROLD STONER: This is still experimental and everything we use is given to us. The only cost we have is transporting the material from the treatment plant to our nursery and this amounts to about $1/yd. I will probably have these figures for you next year but at present I just haven't figured it out.

MODERATOR SHUGERT: Could Bruce Briggs explain his pallet or box technique of sticking cuttings — size, depth, handling?

BRUCE BRIGGS: The size of the box was determined by the way they fit into the sheds and the way they are handled by the equipment. We began with a 4 × 8 foot box but are now using a 4 × 6 foot.size. They are 6 inches deep and made of steel with 2 by 4's beneath to hold them off the floor. We are using

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sawdust and perlite in the box as a medium because of the lightness; we use this for almost everything except conifers which we stick in straight perlite with sawdust beneath. The boxes are moved from one area to another with the forklift tractor. They are set down in the propagating area so that the openings beneath them line up and this forms two tunnels beneath them. The floor is heated and this traps heat beneath them. We have controls every 12 feet so you can change the conditions every 12 feet down the rows of boxes.

We are having a problem with algae on the floor because we are running the mist 12 and 14 hours a day. I don't know what would happen if we used the porous concrete which was mentioned today — that is whether the algae would eventually plug up even the porous concrete.

ELTON SMITH: The porous concrete needs to be only about 2 inches thick and we've had no trouble running small tractors over them. Also, the floor is cleaned with a small industrial cleaner and this is apparently taking care of any algae problem.

MODERATOR SHUGERT: Mark Cunningham, how many years are you away from producing clematis from tissue culture? And is your total *Gypsophila* 'Bristol Fairy' production by tissue culture?

MARK CUNNINGHAM: I don't know when we'll have a breakthrough on the clematis. I've been working on it for 2 years now and have produced large amounts of callus tissue but I have not been able to get the callus to break bud. With respect to the *Gypsophila* question, only our stock plants are produced by tissue culture.

MODERATOR SNYDER: Jake Tinga, has any experimental work been done using other than plain water in the radiation barrels?

JAKE TINGA: I have heard that in Maryland 6 inch rock and a gallon of anti-freeze in barrels is being used but I personally feel that if I have to go to this much trouble I would just as soon put in a second barrel and double my radiation.

MODERATOR SHUGERT: In a recent publication of the American Rhododendron Society there was an article stating that, contrary to popular belief, old rhododendron plants produced the best cuttings and that continued propagation from young plants will lead to the eventual decline of the cultivar. I would like to have some discussion on this point.

JIM WELLS: This is a reprint of an article written earlier by Guy Nehring and I was dismayed when I read it because I think it is repeating a fallacy — I think it is quite wrong. Most of the

standard rhododendron cultivars that we have today have been around for a long time, many going back to about 1850 in England. I can't speak for what the plants were like then as compared to now but I can say that in my 30 years of growing rhododendrons such as 'Roseum Elegans', I have seen no reduction in the vigor of the plants from what they were when I first started growing them 30 years ago. This proposition has also been put forward for other plants, such as roses and carnations, and I believe the deterioration that has been observed for such crops has been due to the infection of these crops with viruses in the past. But I must emphasize that during 30 years of working with rhododendrons I've observed no reduction in vigor of any of the cultivars.

ANDY KNAUER: Plants which are grown for many generations under many types of environmental conditions do have a propensity for somatic genetic change and I think that such changes, not necessarily "declines", can account for a number of changes which have been observed. When this occurs, we can end up with a multiplicity of clones all with the same name.

GUS MEHLQUIST: What Andy has said is true but I have observed another situation in the case of 'Roseum Elegans' because it was often grafted on 'Roseum Elegans' seedlings. Occasionally the rootstock would sprout and produce a plant so close to 'Roseum Elegans' that you could hardly tell them apart. I think that some of these, for instance 'Roseum Elegans Pink', have simply come up from the rootstock.

With respect to Mr. Nehring, I think he had something else in mind. He was influenced by an article he read which indicated that plants do deteriorate with rapid propagation. This is true with plants where virus is a factor but, thus far, there is no indication that viruses are a factor in rhododendron production. One point which Mr. Nehring explained to me and was not made clear in that article is that when you take cuttings repeatedly from fast growing plants you often have cuttings which do not have enough carbohydrates to make a good plant in the normal length of time. If you place such cuttings in a Nehring frame, which Mr. Nehring always used, you may end up with inferior plants because they never catch up. If these same cuttings are grown in a well-equipped greenhouse they will catch up.

MODERATOR SHUGERT: What is the best way to get rooted cuttings of *Acer*, *Viburnum*, *Prunus*, etc. through the first dormant period following rooting?

JIM WELLS: Use supplemental lighting.

PETER VERMEULEN: If you use supplemental light the

cuttings will flush and grow and there will be no dormant period; the question referred to getting them through the first dormant period following rooting and there may be some reason why this individual wants them to go into dormancy. We have experience with all three of these genera from softwood cuttings. We carry them through in a cool, controlled temperature structure at 36° to 40°F. They go into dormancy after rooting and are allowed to flush gradually in the spring.

JIM WELLS: In my brief respond "use supplemental lighting", I did not mean that this was the entire answer. I believe it is important for many plants that can be rooted and then do not come through the following year. The first thing needed is to get them to make a move towards growth; get the buds to swell or get some new growth on the top of the cutting. After the new growth has been obtained then you must do as Pete has said, carry them through in a controlled, cool environment — you can't just let them freeze.

BILL CURTIS: In our operation we hold the plants until they're well rooted and then put them out in a coolhouse and leave them until they start growing in the spring. As soon as they start pushing in the spring we pot them. We have very good luck using this method with the deciduous magnolias, viburnum and similar plants.

MODERATOR SNYDER: In visiting Princeton Nurseries yesterday, I understood that they fall sow *Cercis canadensis* with no scarification treatment. Could someone verify this for me?

BILL FLEMER: The seeds are not scarified; they are a very northern strain (from Wisconsin) and have a pronounced dormancy requirement, as opposed to those from more southern areas. They are sown when we receive them, about October 15, with no scarification. Their dormancy is satisfied in the open ground during the winter and they germinate very well in the spring.

MODERATOR SNYDER: Were those seeds hard or were they soft?

BILL FLEMER: We received the seeds in the pods and so they are not as hard as if you were to buy them from a seed dealer. We immediately removed them from the pods and sowed them in the field.

MODERATOR SNYDER: Another question for you, Bill: what is a reliable, safe herbicide to use prior to sowing seed in the fall (October)?

BILL FLEMER: I don't know of a safe one and I wouldn't use one in the seedbed areas. What we do, is to treat with Vapam in the fall to kill as many of the weed seeds as possible.

We apply the Vapam, till it in and then put on 2 inches of water from the irrigation lines to seal in the gas so that it will do its work. But I would be very much afraid to use any herbicide in the seedbed area. With deep-sown fall seed we have treated with Paraquat during warm spells in Jan. and Feb., but this should only be used on seed which are planted 1 inch or more beneath the soil.

BEN DAVIS: We use locally collected *Cercis* seed and find that we have to scarify them for 20 to 30 minutes with sulfuric acid and then stratify for 60 days.

With respect to the question about a herbicide for seed beds, we fumigate with methyl bromide. One thing we tried this year — not in seedbeds, but on peach seeds — was the use of Simazine at 2 lbs of 80W/A applied in an 18 inch band. We had fantastic weed control and the peach seedlings seemed to grow better than those which were not treated.

MODERATOR SNYDER: I would like some comments on rooting kalmia cuttings.

GERRY VERKADE: Dr. Jaynes doesn't feel that hormones will help in the rooting of kalmia but I do. It is also important that you stick them in a vapor proof chamber with a peat mix and bottom heat. Although Dr. Jaynes says that October is the best time to root them, I'm beginning to think November is better. One batch of cuttings which I stuck on October 15 and treated with 0.8% IBA gave 95% rooting by January but the big problem is to get them to break after rooting. About 60% of these cuttings have started growth but the others are just sitting there.

Dick sent me 12 cuttings of one clone with a note which said "impossible to root". This was a challenge to me so I treated two cuttings each with 5 different hormones or combinations and grafted two so I wouldn't lose the start. The 2 cuttings treated with Chloromone both rooted, so that's 100%. Those that didn't root were still alive so I grafted them also and will hope to try them again this year.

VOICE: I think it is very important, as Gerry has said, that you use a tent in which to root them and not mist; the rooting will go down considerably if you use mist. Also, it takes about 4 to 5 months for most kalmia to root but the rooting is very much dependent upon the particular clone. Dr. Jayne's No. 137 Redbud roots about 70% for me but others will root up to 90 to 95% using 1% IBA with a little Benlate and Manzate added.

MODERATOR SNYDER: Do we have a chemical that controls juvenility in woody plants?

DICK ZIMMERMAN: Gibberellins are the chemicals that have as great a role as any in controlling juvenility. There are

many different gibberellins and the chemical structure of the compound is very important to it's action but we still have a long way to go to understanding it's role and importance in controlling juvenility.

MODERATOR SNYDER: What standard is used for camperdown elm (*Ulmus* × *Vegeta* 'Camperdownii')?

BILL FLEMER: *Ulmus pumila*.

JORGE LEISS: *U. pumila* makes a terrible bole with camperdown elm. Use English elm (*U. procera*) or a hybrid if you can get it.

MODERATOR SNYDER: Is there a compatible rootstock for *Nyssa sylvatica*?

BILL FLEMER: Use *Nyssa* seedlings.

MODERATOR SNYDER: What is a good understock for *Corylus avellana* 'Contorta' that doesn't sucker?

BILL FLEMER: *C. colurna*.

JORGE LEISS: That will sucker; put *C. contorta* on it's own roots and let it sucker.

BILL FLEMER: Jorge is right in that all *Corylus* understocks will sucker but there is a graduation. If you use *C. americana* it will sucker terribly, on *C. avellana* it will sucker quite a lot but we get the least suckering on *C. colurna*.

MODERATOR SHUGERT: Is anyone propagating *Alnus glutinosa* vegetatively?

JORGE LEISS: We have propagated by cuttings a cultivar called 'Imperialis', which is a nice cutleaf form. We use No. 2 Hormodin and it roots in about 10 to 12 days; it roots very easily but *A. glutinosa* is usually propagated by seed.

MODERATOR SHUGERT: Will Pete Vermeulen please explain how he reuses the plastic in his houses.

PETE VERMEULEN: Several people noticed that we were rolling our plastic off and we've been doing this now for 3 years. Our houses are of the quonset style, 15 feet wide and 125 feet long. The houses have a 2 × 4 furring strip along the bottom on each side. The poly is nailed on to the 2 × 4 with a 1 × 2 furring strip and the poly is run across the house, pulled drum tight and nailed to the other side. On the second side we nail the furring strip with double-headed nails. In spring we remove these double-headed nails; the furring strips used are 10 feet long and we have one person for each 10 foot section. We begin rolling the plastic, attempting to keep it straight and tight and we continue to roll right over the house and down to the other furring strip where it is tied down and then covered with black plastic to keep the sun off of it. These houses are running

east and west so we always roll from the south to the north side. When fall comes we simply reverse the process and roll the plastic back over to the other side and renail it. Some of the polyethylene we are using for the third year. We have tried several different plastics but the one that has proven best for us we obtain from Growing Systems, Inc., 2951 North Wells Street, Milwaukee, Wisconsin 53212.

MODERATOR SHUGERT: Dr. Snyder and I wish to thank all of you for your participation in the Question Box Session. It has been our pleasure to serve you as moderators and we will now adjourn.

Thursday Morning, August 26, 1976

The moderator for the morning's program was Richard Bosley.

UNUSUAL PLANTS IN JAPANESE NURSERIES

ROBERT L. BAKER
Department of Horticulture
University of Maryland
College Park, Maryland 20742

Over the centuries Japanese horticulturists have developed an extraordinary number of cultivars and training techniques which are unfamiliar to American gardeners. In the spring of 1974 I spent several months in Japan visiting gardens, nurseries, botanic gardens, and natural areas in an effort to familiarize myself with the native and cultivated flora.

There are several nursery areas where unusual plants may be seen in abundance. Angyo, a few miles north of Tokyo, is one of the major centers. In this district may be found a great many small specialty nurseries, some of which may occupy 1/2 acre or less. Although in some cases the stock plants may be grown directly in the ground, more often all plants are grown in ornamental containers of varying size. Usually they have been carefully pruned and shaped as specimen plants. Most of these rare dwarf, contorted, or variegated plants will continue to be grown in this way when they leave the nursery. If they are used in the landscape, they may be planted as accents in small-scale compositions. Many similar nurseries are located in or near Ikeda and Yamamoto, south of Osaka. Among the specialties of these nurseries are bonsai and bonkei (tray land-

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scapes), and the training of larger specimen trees for landscape use. The town of Utsunomiya near Nikko is a center of Satsuki azalea production. Here many of the finest growers are located on small city lots where every available space is utilized for propagation, growing, and display. In the vicinity of Kurume, on the southern island of Kyushu, there are many large nurseries which specialize in Kurume, Hirado, and other azaleas.

Of great interest to collectors are the many cultivars of *Rohdea japonica*, valued for their dark leathery leaves which may be broad or narrow, curled, twisted, or striped and mottled. Dense clusters of scarlet fruits add further interest. They are displayed in special tall blue or black glazed pots. Of equal interest for its foliage variations are the many cultivars of *Cymbidium virescens*. These are also displayed in tall containers of distinctive form. The cultivars of *Selaginella tamariscina* (synonym: *S. involvens*) are not well-known outside of Japan. These compact plants, seldom over 6 inches tall, somewhat resemble the dwarf forms of *Chamaecyparis obtusa* or *Calluna*. There is great variation in the form of the branchlets and in color of foliage which ranges from vivid green to bright yellow or orange. Especially valued are those which turn red or orange during the winter. They are displayed as single plants in small dull glazed or unglazed pots. Other upright species of *Selaginella* are also cultivated. In one nursery in Angyo we saw a large collection of *Psilotum* cultivars — some dwarf and twisted, others upright with bright yellow new shoots. There are also many handsome cultivars of *Liriope* and *Ophiopogon* noted for variegated foliage or dwarf habit; 'Black Dragon' has leaves of deep bronze color. In the research garden of the Takeda Chemical Co. in Kyoto we found a specimen of *Daphne genkwa* with exceptionally large bright rosy-pink flowers. We also saw the red succulent fruit of *Daphne odora* for the first time. *Pinus thunbergiana* 'Corticosa' is highly prized for its thick irregular corky bark. It is sometimes used as an understock for *Pinus parviflora* in bonsai work, or it may be propagated by cuttings as a specimen. *Nandina* cultivars have been selected for variations in leaf shape and color as well as growth habit. Most impressive are the extreme dwarf types only a few inches high with tiny leaflets. There is a strain of *Ginkgo biloba* in China and Japan which develops pendulous woody growths at the base of the lower branches of old trees. These are propagated by grafting for use in bonsai as well as landscape specimens. Another unusual plant which we saw in one of the bonsai nurseries in the well-known village of Omiya near Tokyo was the white-fruiting form of *Prunus tomentosa*.

Dwarf plants, whether induced by training or true genetic dwarfs, have long had a special fascination for the Japanese.

Many genetic dwarfs have come from the southern island of Yakushima, such as an *Hosta* of undetermined species. A plant of this type when grown in a fine container might be used as a small accent plant in a bonsai display. There are several dwarf selections of *Jasminum* including one with white-margined leaves. In one of the Angyo nurseries we saw a cultivar of *Morus* with extremely crinkled leaves and red fruit which was described as a great rarity. A dwarf *Ilex serrata* with abundant tiny red fruits is grown specifically for bonsai use. One typical example of a large tray landscape (bonkei) included dwarf *Ulmus*, *Ilex crenata*, *Cryptomeria*, *Rosa*, *Erica*, *Acer*, *Spiraea*, *Rhododendron indicum*, *Scutellaria*, *Serissa*, in addition to some bamboo and groundcovers of *Sedum* and *Selaginella*. All of these plants were growing in a shallow clay tray about 2 feet long and were pruned to scale.

The Satsuki azaleas are well-known in the West, but new cultivars are constantly being introduced by Japanese growers. Like the dwarf plants they are seldom used in landscape plantings, but rather are grown in containers as specimens for exhibition. Training begins with the newly-rooted cutting which is pruned to a single stem and staked, later to be wired and trained in a modified bonsai style. In central Kyushu we observed the field propagation of *Rhododendron kiusianum*, *R. obtusum*, and *R. indicum* cultivars. Some plants are grown on in the field while others are potted and trained as specimens. Superb cultivars of the large-flowering, chimaeral Hirado azaleas are to be found at the Kurume Horticultural Research Station and in a few of the nurseries nearby.

Some of the small nurseries at Ikeda and Angyo are devoted primarily to maples. *Acer japonicum*, *A. palmatum*, and *A. buergeranum* predominate among the vast array of cultivars available.

In addition to rare species and dwarf cultivars, the other major group of unusual plants to be found in Japanese nurseries are those with variegated foliage. In a photograph of a typical section of a display table at a nursery in Yamamoto may be seen variegated *Ulmus*, *Kerria*, *Camellia*, *Chaenomeles*, and *Phlox*. Other excellent variegated specimens observed included a *Clivia* with scarlet flowers, *Hemerocallis*, *Iris japonica*, *Lilium* sp. (*L. longiflorum*?), *Polygonatum*, *Corylopsis*, *Hibiscus syriacus*, *Osmanthus* sp. (*O. heterophyllus*?) with pink fruit, *Parthenocissus tricuspidata*, *Tracelospermum*, *Wisteria*, and *Zelkova*.

We visited a notable nursery near Ikeda where *Pinus thunbergiana*, *P. densiflora*, and *P. parviflora* were grown and trained for bonsai and also for landscape use. The larger trees, some of which may be 200 years old, have been transplanted

frequently and are grown on mounds, ready for easy removal. Fine old specimens sell for $10,000 or more. Such trees are pruned, thinned, and trained with extreme care on an annual basis. The branches are fastened to a bamboo support while the twigs are tied down or pulled up with twine to obtain the desired angle. Roots are sometimes gradually exposed to produce bizarre effects. Out in the fields we saw rows of young pines in training, the branches either tied with ribbons to bamboo stakes or trained with wire around the stems.

Many of the rare plants grown in these nurseries may be found for sale in the garden departments (usually on the roof) of major department stores in Tokyo, Osaka, and Kyoto. The diversity of distinctive plant materials available in department stores and flower shops is most impressive. For example, a modest flower shop in a residential section of Tokyo contained a good selection of bonsai including *Jasminum*, *Zelkova*, *Acer*, and *Prunus mume*, as well as an excellent collection of alpines such as *Houstonea*, *Phlox*, *Dianthus*, *Rhodohypoxis*, and *Gentiana*. In this shop also were fine specimens of *Shortia* in full flower growing on moss-filled wire frames placed in a large saucer of water. The western visitor is constantly amazed by the ingenuity and passion for fine detail of the Japanese people.

FUNGICIDE ALLERGIES?

E. STROOMBEEK

Roemer Nursery
Madison, Ohio

The title for this short presentation is posed as a question and instead of singling out just fungicides I would like to broaden the scope and ask the question, "Horticultural chemical allergies, or worse?"

In our meetings of the 1950's and '60's, we were constantly reminded to use fungicides like Captan, Phaltan, Phygon and Terraclor in preventive spray-programs in our propagation. What was the attitude of the average grower or propagator to these relatively new materials? We were supposed to be very cautious, read the labels carefully and follow all the instructions we were given conscientiously.

But did we really do all those things? Thinking back to my experiences as a propagator in Lake County, I have to admit that I, as well as most of the growers that I knew and met, were rather casual and even lax when it came to spraying. After all, the labels were often not too specific as far as warnings for dangerous consequences were concerned. And word of mouth

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But did we really do all those things? Thinking back to my experiences as a propagator in Lake County, I have to admit that I, as well as most of the growers that I knew and met, were rather casual and even lax when it came to spraying. After all, the labels were often not too specific as far as warnings for dangerous consequences were concerned. And word of mouth

in our area was that fungicides were really rather harmless. I don't recall ever wearing even an ordinary dust-mask while spraying the greenhouses with fungicides on a regular basis.

In 1960 I started my own operation and continued merrily blasting away at cuttings with a fungicide every 10 days, of course without bothering with face protection. I never paid any attention to the fact that every winter I was constantly plagued by sore throats and laryngitis that continued on without let-up for months on end. That inconvenience was blamed on our well-known northern Ohio climate. After all, what can you expect when you run constantly in and out of warm greenhouses into a howling "north-eastern" or into our never ending snow squalls. But that explanation was really too pat. After much persuasion by my wife, I finally went to see a nose and throat specialist in 1967. One of the first questions he asked me after taking a good look at the sorry mess that became visible when I opened my mouth, was what did I do for a living. I told him that I spent a good deal of my time during the winter working in greenhouses. He immediately suggested that I pay a lot closer attention to the chemicals I was using on a regular basis because my throat condition showed no indication of a common cold infection. He admitted that he was unfamiliar with the effects of such chemicals, but he suggested that my problem might be some kind of an allergy.

It had really never occurred to me that there might be a connection between my throat condition and the sloppy spraying habits I was practicing during the winter in the confined greenhouse interiors. But to make a long story short I took his advice, started wearing a mask whenever I was spraying with fungicides, especially when using Captan, and that was the end of my bouts with sore throat and laryngitis.

Why did I single out Captan? All I have to do even today is walk into a greenhouse freshly sprayed with Captan and within a couple hours I am coughing again. I have discussed this experience with other growers and plant-pathologists and they have told me about similar experiences.

Why did I bother to tell this distinguished audience about this personal experience with fungicides? Because a lot of changes have occurred during the last 6 years with respect to chemicals. Attitudes toward the environment in general and chemicals in particular have changed drastically. E.P.A. has entered the scene, several important pesticides have been banned, and agriculture and horticulture are being hampered in their activities by a severe curtailment of chemicals still allowed for regular use. In my opinion this approach smacks somewhat of overkill.

On the other hand I, like numerous people in this audience, have knowledge of accidents or of cases of health deterioration that took place not only as a result of working with the more dangerous chemicals, but also from working with seemingly harmless materials used in our industry. I have been told by extension people that a number of the older materials including Captan and Benlate are being re-investigated at the present time. I for one consider myself fortunate that the potential danger of chemicals was pointed out to me in a rather simple incident and ever since we have become scrupulously careful when working with chemicals at our nursery.

MANAGEMENT OF SMALL POOLS: VEGETATIVE PROPAGATION OF SELECTED WATER PLANTS[1]

JUDITH L. SHIRLEY[2]

U.S. National Arboretum
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U.S. Department of Agriculture
Washington, D.C. 20002

Abstract. The development and maintenance of the aquatic garden at the U.S. National Arboretum, Washington, D.C. is discussed as a general guide for the management of small pools. Information is given on the culture and vegetative propagation of hardy and tropical water-lilies, lotus, and other aquatic plants. Methods for the control of algae and insect pests are also described. The aquatic plants grown in the pool in the 1976 season are listed.

Aquatic displays in parks and gardens in our urban areas are generally open areas of high visibility and, consequently, intense visitor interest. Annual vegetative propagation, seasonal maintenance, and advance planning are necessary to maintain an exciting summer display, year after year. This paper will describe the maintenance of an aquatic garden, the culture and vegetative propagation of hardy and tropical water-lilies, lotus, and various aquatic background plants, and the control of algae and insect pests.

THE POOL — SIZE, CLIMATE AND CONTAINERS

A large display pool at the U.S. National Arboretum, Washington, D.C., partially encompasses the Administration Building. This concrete pool covers approximately 1/3 acre and contains 115,000 gallons of water from 22″-30″ deep. Twenty-six

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[2] Plant Propagator

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fountain nozzles arranged in a regular pattern at the water surface shoot a constant stream of water 4′ to 5′ above the surface of the pool, breaking up the glass-like appearance of the water surface. An underwater lighting system provides enough light at night to frame the pool and the auditorium which it surrounds. The water is not artificially heated.

The climate of Washington, D.C. is a temperate, USDA zone 7[3] (average annual minimum temperature 0°-10°F). Typically, the last frost of the spring occurs in mid-April and the first frost of the fall occurs in mid- to late October. The display pool may be covered by a thin layer of ice for periods of perhaps a week, several times during the winter months. All of the aquatic plants are grown in square wooden containers, the dimensions of which vary from 20″-26″ on a side and 14″-16″ in depth. This past summer, there were 50-60 display plants in the pool, showing about 40 different species and forms. Many of our hardy aquatic plants, particularly the hardy water-lilies (*Nymphaea* spp.), remain in the pool throughout the winter and are the basis for our late spring to mid-summer aquatic display.

HARDY WATER-LILIES (Nymphaea spp.)

In late April or early May, the hardy water-lily rootstocks are dug up, divided and replanted in boxes with a fresh soil mixture. Young, small "branchés" from the older rootstocks should be used — those that have developed and grown the previous year from a bud or growing point on an older rootstock. These young rootstocks, each with a growing point, can be broken or cut from the old rootstock and one or, at the most, two pieces planted in the same tub. Hardy water-lilies grown in containers can be considered short-lived perennials. Old rootstocks are considerably less vigorous and less floriferous than the young rootstocks produced each year from the multitude of growing points on older, second-year rootstocks. In this way, the rootstocks grown in containers quickly develop into a tangled, interconnected mass, physically breaking apart as a result of vigorous growth. I have found that most hardy water-lilies grown in this size container must be divided at least once every 2 years or the vigor of the plant is greatly reduced. Symptoms of overcrowding — mounding up of leaves held above the water surface around the crown of the plant, small flowers, many hidden by the leaves, and a great reduction in the total spready of the leaves over the water — becomes apparent late in the season of the second year of undisturbed growth. Certainly, some hardy water-lilies are more vigorous than others and need more frequent dividing. A replacement of the soil mixture at the time of division means a tremendous in-

[3] Plant Hardiness Zone Map. U.S. Dept. Agr. Misc. Publ. 814. Rev. 1965.

crease in the nutrient availability to the young replanted rootstock. The young rootstocks should be planted horizontally or at a slightly oblique angle to allow the growing point to be visible at the soil surface.

All of the aquatic plants are grown in the same soil mixture. The tubs are first filled 1/3 to 1/2 full of rotted, aged elephant manure (or general zoo manure), donated by the National Zoological Park, Smithsonian Institution, Washington, D.C. The remainder of the box, to within 1″ of the top, is filled with a loam topsoil. Organic soil amendments such as peat moss and leaf mold should be avoided. The by-products of their decomposition under water can be harmful to fish and plant life. The manure serves as a source of nutrients readily available to the growing plants, but out of contact with the water surface, thereby not contributing to excess algal growth. After planting, a layer of rocks, each the size of a small chicken egg, is spread over the top of the box but not covering or obstructing the growing point or crown of the plant. This presents a nice appearance, helps keep the pool clean, and acts to initially hold the water-lily rootstocks in place until new growth begins and feeder roots develop. It also prevents our resident fish (Nishiki Koi — Fancy Japanese Carp) from clouding the water when they feed and spawn in the plant tubs.

The flowers of hardy water-lilies open in early morning and close in late afternoon, individual blossoms lasting about 3 days. Typical commercial cultivars produce flowers 5″ to 8″ in diameter. Blooms usually float on the water surface, although some *Nymphaea* cultivars such as 'Sunrise,' a pure yellow, have flowers that rise 2″-4″ above the surface on a stiff stalk. Flower color varies from pure white, yellow, to pink and deep rose. For a blue flower, you will have to grow a tropical water-lily. Two hardy water-lily cultivars that are adapted to areas that do not get a full day's complement of direct sun are 'Chromatella' (pure yellow) and 'Commanche' (yellow to rose-apricot at the base of the petals). Other cultivars that have performed well are 'Escarboucle' (deep red petals, white sepals), 'Gonnera' (multiple layers of white petals), 'Rose Arey' (bright pink), 'Attraction' (pink to red petals, white sepals), 'Splendida' (pink), 'Masseniello' (light pink), and a vigorous pygmaea type, 'Joanna Pring' (pink, 2″ flower). To overwinter, the hardy water-lily containers are moved to deeper water (8″-10″ of water over the tub), below the freezing line, so that the soil surrounding the rootstocks is never frozen.

TROPICAL WATER-LILIES (Nymphaea spp.)

Tropical water-lilies have to be propagated anew each year or purchased as young plants; they do not overwinter in the

pool in our climate. In late October, after the first frost, the plants are dug. Beneath the large fleshy crown, small, round, walnut-size tubers occur which can be broken or cut off, cleaned, stored over winter, and sprouted the following spring. Before storing, the tubers are cleaned and dipped in benomyl (1 tbsp/gal) and dried for 1/2 day. They are then stored in a jar with holes punched in the top and layered in a mixture of slightly moist sand and sphagnum. These "stratified" tubers are kept at a temperature of 45° to 50°F until early March.

One method of sprouting a tuber is to plant it in a 5" pot, 2" deep with the growing point up, in a soil mix of 1/2 loam and 1/2 sand. The top 1/2" of the pot is covered with sand and submerged 2" over the top of the pot in water at 75°F. In 2 to 3 weeks, the tuber will sprout and when the leaves become 1½" to 2" in diameter, the sprout and the roots forming on the sprout above the tuber can be pinched off and potted. In this manner, the tuber may sprout two or three times. It is not necessary to pinch off the sprout if only one plant per tuber is desired; simply continue to grow the sprouting tuber. If more than one sprout should form simultaneously on a tuber, one should be removed. Multiple-crowned plants are less vigorous and the flowers tend to be smaller. As the sprouted tubers continue to grow, they should be repotted several times; pot-bound plants have a tendency to go dormant and are slow to recover. Another method of sprouting tropical water-lily tubers is to simply place the tubers on a screen 2" below the water surface and pot up the sprouted tubers when the leaves are about 2" in diameter. Non-viable tubers that have rotted during storage are easily recognized and removed.

The tropical water-lilies are transplanted into tubs in the pool as soon as the water temperature reaches 70°F (early June). The shock of transplanting into cooler water can so stunt the growth that it more than offsets any advantages hoped to be gained by early planting.

Tropical water-lilies in the genus *Nymphaea* can be divided into two groups: day-bloomers and night-bloomers. The day-bloomers have thin-textured light green leaves, occasionally mottled or striped deep purple, and hold their flowers aloft 12"-15" on stiff stalks; flowers open in mid-morning and close at dusk. The leaves of tropical night-bloomers are thicker in texture and deeper green in color to a deep maroon. The flowers, also held aloft on thick stalks, open at dusk and close the next morning between 10 a.m. and noon. The flowers generally last 3 days and the opening and closing of individual flowers depends on the degree of cloud cover on a particular day and the latitude of the pool. Among the day-blooming tropicals, a few will reproduce themselves by forming small plantlets on the

leaves. These are referred to as "viviparous" tropical water-lilies and the offspring as "vivips". On the upper surface of the leaf, at the point where the leaf stem attaches to the floating leaf pad, a small bump will form and in a short time a miniature water-lily develops. As the leaves of the vivip expand and a crown and roots form, the parent leaf begins to decay. These vivips can be potted up when their leaves are 2" in diameter. Or, to encourage undisturbed and faster growth, place a pot of soil under the leaf pad still attached to the parent plant, holding the leaf down on the pot with a few rocks. The vivip sends roots down into the soil and develops into a strong young plant in 3 to 4 weeks. The parent leaf eventually decays and the vivip can then be severed from the parent plant. The water depth over the vivip should be gradually increased from 1" to 4"-5" as the vivip grows. The degree to which a viviparous plant will produce these vivips is dependent on the latitude, being much greater in Florida (where the vivips produce miniature blossoms while still attached to the parent plant) and decreasing as you move north. The cultivar 'Panama Pacific' is strongly viviparous in Washington, D.C.

Both tropical and hardy water-lilies require high soil fertility to bloom freely and consistently. Throughout the growing season, at 2-week intervals, a supplemental fertilizer is applied in tablet form (20-10-5, 5 gram size). These tablets, three per tub, are pushed down into the soil around the crown of the plant. A mixture of hardy and tropical water-lilies blooms from early June through October. The hardy nymphaeas begin blooming in early June and continue through August; the tropical nymphaeas produce their best flowers from July through October.

CONTROL OF ALGAE AND INSECT PESTS

Very few diseases and insect pests are harmful to water-lilies. Nevertheless, aphids are unsightly and can cause minor injury to the leaves and flowers. The best cure is to simply wash the insects off the underside of the foliage and flowers by using a fine spray hose nozzle, allowing the fish to feed on the floating insects. Spraying the foliage with 1/2 strength malathion (50% WP) will also give control without harming plants or fish. Various larvae may feed on water-lily pads, creating a lace-work effect. This can be controlled by sprinkling granules of a larvacide called temephos on the foliage. This does not have any burning effect and provides excellent control for mosquitoes.

Unwanted algal growth is a frequent problem in pools. Fish, if there are enough of them, offer good control. Using soil mixes for planters that do not contain organic matter, or keep

the organic matter out of direct contact with the surface water, also reduces algae. Primarily to control algae, but also to improve appearance and create an illusion of depth, the water in the Arboretum display pool is dyed with a black, soluble, crystalline dye. The dye reduces the penetration of sunlight into the water and thereby limits the algal growth. Numerous chemicals and specific algicides are available (e.g. Algimycin, potassium permanganate, copper sulfate, etc.) but should be used with great care because of the adverse effects an overdose might have on fish and plant life.

LOTUS (Nelumbo spp.)

Another outstanding hardy aquatic is the lotus (*Nelumbo spp.*) of ancient legend. Standing 3′ to 7′ out of the water, the large, round leaves (to 2′ in diameter) and cup-shaped flowers (8″ to 10″ in diameter) are held aloft, singly, on stiff straight stalks. The lotus vegetatively reproduces itself by means of slender, fleshy rootstocks which form a joint every 12″-18″ with a tapered growing point at the end. Plants are divided in the early spring of every second year after the last chance of frost. The interconnected rootstocks are dug up, separated, and one or two fleshy joints, each with a growing point, are replanted. The rootstocks are planted horizontally, or at a slightly oblique angle, with the growing tip 1/2″-1″ above the soil surface. These exposed growing points can be killed by physical damage as well as by frost if divided too early in the spring. The primary horticultural species, the East Indian lotus, *Nelumbo nucifera*, is native to East Asia. Flower color varies in the single-flowered forms from pure white to deep rose-pink; double-flowered forms with pink flowers are also known. Flowers generally last for 3 days, the petals beginning to fall from the open, third-day flower — exposing the developing many-seeded pod. Another very hardy and often overlooked lotus is the sulfur-yellow flowered American lotus, *Nelumbo lutea*, native to undisturbed water in eastern U.S.A., from New York to Minnesota and south to Florida and Texas. *Nelumbo caspica*, with deep pink flowers, native to the Crimea, is perhaps the only lotus that is not reliably hardy in Washington, D.C. In this case, the rootstocks are dug up in late fall, treated and stored in a manner similar to a tropical water-lily tuber, and replanted after danger of frost is past in spring.

AQUATIC BACKGROUND PLANTS

A superbly edible crop, and one that provides an excellent, grass-like background for showing off other aquatics, is the Chinese water-chestnut (*Eleocharis dulcis*). The brown, bulb-like corms are dug in the fall after the top growth dies back

from frost. They are cleaned and dipped in hot water (130°F) for 2 minutes to decrease rotting, and are stored in slightly moist sand and sphagnum (1:1) in jars or plastic bags at 40°F. In late April, the corms are potted in 5″ to 6″ pots with the growing tip of the corm at the soil surface. They sprout readily in greenhouse conditions, and in 3-4 weeks are placed in water to the depth of the pots. Young plants, with rush-like foliage 12″ high, are transplanted to tubs in the display pool in late May. The young plants should not be completely submerged; 2″ to 3″ of water over the planting tub throughout the growing season is sufficient.

The list of possible aquatic display plants is limited only by the prevailing climate and one's imagination. The following aquatics, not previously mentioned, were grown this past season and created an interesting educational display as well as the desired ornamental effect under the cultural and climatic conditions described in this paper.

Tropical, non-hardy Nymphaeas: 'Director Moore' (deep blue, TD*), 'Mrs. George Pring' (white, TD), 'Isabelle Pring' (white, TD, not reliably viviparous), 'Rio Rita' (deep pink, TD, not reliably viviparous), 'Pamela' (light blue, TD), 'Pink Platter' (pink, TD), 'Blue Beauty' (light blue, TD), 'Missouri' (creamy white, TN*), 'Emily Grant Hutchings' (deep pink-red, TN), 'Mrs. George C. Hitchcock' (rose-pink, TN).

Additional tropical, non-hardy water-lilies: Giant Water Platters (*Victoria cruziana, V. amazonica, V.* ×'Longwood Hybrid' [*cruziana* /F/ × *amazonica* /M/]), Indian Gorgon Plant (*Euryale ferox*).

Hardy lotus (*Nelumbo nucifera* cultivars): 'Alba Grandiflora', 'Ohga', 'Pygmaea Rubra', *N.* × 'Maihiren' ('Ohga' × *N. lutea*).

Additional hardy aquatics: Yellow Flag Iris (*Iris pseudoacorus*), Basket Willow (*Salix viminalis*), Hardy Water-Canna (*Thalia dealbata*), Rose-Mallow (*Hibiscus moscheutos*, many cultivars), Zebra Rush (*Scirpus tabernaemontani* 'Zebrinus'), Narrow-Leaf Cattail (*Typha angustifolia*).

Additional non-hardy aquatics: Green Taro (*Colocasia esculenta* var. *antiquorum*), Imperial Taro (*C.e.* var. *a.* 'Illustris'), Canna (*Canna* 'Endeavor', *C.* 'Erebus'), Dwarf Papyrus (*Cyperus papyrus* 'Nanus'), Bur-Head (*Echinodorus palaefolius*).

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* TD — Tropical day-bloomer

* TN — Tropical night-bloomer

SLOW-RELEASE FERTILIZERS — PAST, PRESENT AND FUTURE

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Abstract. Methylene urea reaction products and certain experimental nitrogen sources varying in water solubility were evaluated under a wide range of environmental conditions using woody ornamentals as the indicator plant. Phytotoxicity was dramatically reduced by decreasing the water solubility of the nitrogen sources. Maximum safety and plant growth from methylene urea products was realized with 50 percent of the nitrogen in a cold water soluble form. In the midwest and northeast (Hardiness Zones 3, 4 and 5), a residual of 4 to 6 months was realized with a 3 to 4 month residual in more moderate climates (California). Experimental nitrogen sources exhibited better residual and safety than methylene urea products. This was particularly evident in moderate climates (California) with the trend still evident in the cooler climate of the midwest and northeast. A 12 to 18 month residual was realized with certain experimental nitrogen sources.

REVIEW OF LITERATURE

Nitrogen (N) levels in the root zone of plants is short-lived and must be constantly replenished to assure maximum plant growth and development. In contrast phosphorus and potassium, being a natural component in most soils, are not often limiting. If these elements are limiting, nutrient levels can be increased in the soil by a single application applied every 1 to 2 years. This is not the case with nitrogen; consequently, scientists have been concentrating their research on developing controlled-release N sources.

Research on controlling the release of N began in the mid-40's when urea formaldehyde reaction products (methylene ureas) proved to have controlled-release properties. Subsequent development of this technology was effective at controlling the release of N to meet the biological demands of different crops. The water solubility can be varied from essentially zero up to 100%. N is activated by water and microbial release. Rate of release is controlled by the degree of polymerization, particle size and microbial activity.

In the early 60's encapsulation and matrix modification of highly soluble N sources was investigated. This technology has a number of advantages over previous technology, for example, release of the N can be more nearly matched with biological demands resulting in much greater efficiency of utilization. The matrix concept has not been further developed for commercialization. Encapsulation of soluble nitrogen sources appears to be the most promising new technology. Coating materials and

coating technology are changing very rapidly. New technology suggests residual characteristics of 1 to 2 years is feasible.

MATERIALS, METHODS, AND RESULTS

A number of studies on woody ornamentals grown under a wide range of cultural conditions were conducted at cooperating nurseries and private research stations for the past 3 years.

Rooted Liners in Ohio. Bare root liners were potted in 3″ pots of 3-1-1 soil-peat-sand supplemented with P_2O_5 and K_2O. Fritted trace elements and dolomitic limestone were also applied to assure adequate levels of secondary and minor elements. Various N sources were incorporated at 1 lb of N/cu yd at potting time. No additional fertilizer was applied for the remainder of the test (11 months). The pots were plunged in sand and over-wintered under snow fence covered with plastic.

As shown in Table 1, completely soluble N sources caused extreme injury to cotoneaster and moderate injury to juniper. Modifying the nitrogen release rate by reacting urea with formaldehyde or encapsulating the N reduced the initial injury to an acceptable level (0 to 2%). Subsequent growth varied with the N release characteristics. Maximum growth and plant quality was realized with the encapsulated N. The best methylene urea product ranged from 50 to 66% CWSN, with the slower release (50% CWSN) inducing slightly better growth and quality.

Table 1. Response of *Juniperus chinensis* 'Pfitzerana' and *Cotoneaster apiculatus* rooted liners to methylene ureas (MU) varying in water solubility.

Percent CWSN[3]	Nutrient[1] Source	Percent Injury		Fresh Wt. Tops (gms)		Plant Quality (1 > 10)	
		Jun.	Cot.	Jun.	Cot.	Jun.	Cot.
		2 months*		11 months*		11 months*	
100	Urea	25	90	1.7	1.2	7.0	8.0
75	MU	0	0	5.1	4.8	5.0	6.5
66	MU	0	0	6.8	8.3	3.0	5.5
50	MU	0	0	7.1	9.6	3.0	3.0
	Exp-N	0	0	10.0	12.4	2.0	2.0
	Growers Standard[2]	0	0	7.0	10.7	3.5	3.5
0	0	0	0	4.4	2.9	6.0	6.5

* Months after initial treatment

[1] Fertilizer was incorporated in the potting medium (1 lb N/cu yd) just prior to potting on July 20, 1973. No additional fertilizer was applied.

[2] Three lbs N/1000 sq ft as 16-16-16 (100% CWSN) applied 8/21, 10/28, 4/1 and 6/1.

[3] Percent cold water soluble nitrogen (CWSN) based on the percent nitrogen solubilized in water at room temperature (22°C).

Potted Liners in Ohio. Potted liners (3″ pots) were planted in 1 gal cans of 3:2 hardwood bark-sand mixture. Phosphorus, potassium and minor elements were supplied as above.

Soluble and slowly soluble N sources were incorporated at 1, 2 and 3 lbs N/cu yd. The 1 and 2 lb rates were retreated 7

and 13 months after potting, respectively, using 20lb N/1000 sq ft.

As shown in Table 2, cotoneaster treated with a completely soluble N source (100% CWSN) were damaged severely and/or failed to develop into quality plants. Reducing the N solubility by formaldehyde inactivation greatly increased the safety. This was particularly evident at CWSN levels of 50% or less. Three pounds of N/cu yd (> 66% CWSN) applied only at potting time was inferior to 2 lb N/cu yd followed by 20 lb N/1000 sq ft 13 months after potting.

Table 2. Response of *Contoneaster apiculatus* (potted liners) to incorporated and surface applications of methylene ureas (MU) varying in solubility.

Percent CWSN[2]	Lbs[1] N/cu yd	Nutrient Sources	Maintenance Fertilizer (months)	Percent Injury (4 mo)*	Fresh Wt. Tops (gms) (17 mo)*	Plant Color (10 > 1) (15 mo)*
100	1	Urea	7	9	43	4.5
100	2	Urea	13	100	0	1.0
100	3	Urea	0	100	0	1.0
75	1	MU	7	3	74	7.9
75	2	MU	13	0	90	10.0
75	3	MU	0	67	19	2.8
66	1	MU	7	3	87	9.0
66	2	MU	13	8	99	9.9
66	3	MU	0	17	42	5.3
50	1	MU	7	0	76	7.5
50	2	MU	13	0	98	10.0
50	3	MU	0	0	73	7.3
30	1	MU	7	3	85	9.2
30	2	MU	13	0	91	9.7
30	3	MU	0	0	73	8.4
	0	Control	0	23	19	3.0
L.S.D. .05				15	20	1.8

* Months after initial treatment.

[1] Fertilizer incorporated in the potting medium just prior to potting May 1, 1974. The one and two pound rates were retreated 7 and 13 months after potting, respectively using 20 lbs N/1000 sq ft.

[2] Percent CWSN based on percent nitrogen solubilized in water at room temperature (22°C).

As shown in Table 3, root, top and total plant weights of juniper were inhibited by soluble N source (100% CWSN). Maximum plant development (total weight of tops and roots) using a single application of 3 lbs of N/cubic yard was realized with methylene ureas in the range of 50-66% CWSN. Above or below this range results in too fast a release (75% CWSN) or too slow a release (30% CWSN) to satisfy the biological demands of the plant. A repeat application of 20 lbs N/1000 sq ft applied 7 months after potting to plants maintained on 1 lb N/cu yd since potting time resulted in the best overall development on a cost/performance basis.

Table 3. Root and top weights of *Juniperus chinensis* 'Pfitzerana' as affected by various methylene ureas incorporated in the potting medium.

Percent CWSN[1]	Nutrient Source	Lbs[2] N/cu yd	Maintenance Frequency (months)	Root Weights (gms) (17 months)*	Top Weights (gms)	Total Plant (gms)
100	Urea	1	7	12	9	21
100	Urea	2	13	11	21	32
100	Urea	3	0	5	5	10
75	MU	1	7	45	97	142
75	MU	2	13	34	94	128
75	MU	3	0	33	56	89
66	MU	1	7	46	100	146
66	MU	2	13	48	142	190
66	MU	3	0	46	114	160
50	MU	1	7	54	125	179
50	MU	2	13	51	141	192
50	MU	3	0	56	113	169
30	MU	1	7	51	147	198
30	MU	2	13	45	127	172
30	MU	3	0	42	75	117
	Control	0	0	20	19	39
L.S.D. .05				13	24	37

* Months after initial treatment.

[1] Percent cold water soluble nitrogen (CWSN) based on percent nitrogen solubilized in water at room temperature.

[2] Fertilizer incorporated in the potting medium just prior to potting May 1, 1974. The 1 and 2 pound rates were retreated 7 and 13 months after potting using 20 lbs N/1000 sq ft.

Potted Liners in Connecticut. Potted liners of *Pieris japonica* were planted in 1 gal cans containing a 2-1-1 mix of bark-peat-sand. Phosphorus, potassium, dolomite, lime, sulfur, iron sulfate, and fritted trace elements were added to assure adequate levels of secondary and minor elements. N was incorporated in the potting medium just prior to potting at 1 and 2 lbs N/cu yd using methylene ureas and encapsulated N sources.

The plants were placed in 1 gal cans on May 29. Those plants treated with the low N rate (1 lb N/cu yd) were retreated October 24 (5 months) and those maintained on the high rate (2 lbs N/cu yd) were retreated May 9 (11 months) using 20 lb N/1000 sq ft.

As shown in Table 4, plants treated with a completely soluble N were severely damaged at both rates. When the N release rate was modified by combining ureas with formaldehyde or encapsulating a fast release source the safety was dramatically increased. This was particularly evident at CWSN levels of 50%.

The addition of 1 lb N/cu yd in late May followed by a fall feeding (October 24) of 20 lbs N/1000 sq ft using the experimental N source or methylene urea (50% CWSN) resulted in growth superior or comparable to the growers standard (fertigation applied 450 lbs N/acre/year).

Table 4. Response of *Pieris japonica* to incorporated and surface applications of methylene ureas varying in solubility.

Percent CWSN	Nutrient Source	Lbs[1] N/cu yd	Maintenance[2] Fertilizer (months)	Plant Quality 1 best < 10 dead (17 mo)*	Height (cms) (17 mo)*
100	Urea	1	5	10.0	0
100	Urea	2	11	9.5	3
75	MU	1	5	7.0	16
75	MU	2	11	7.5	17
66	MU	1	5	5.5	19
66	MU	2	11	3.5	33
50	MU	1	5	3.0	39
50	MU	2	11	4.5	30
—	Exp-N	1	5	2.5	48
—	Exp-N	2	11	2.0	49
	Control	0	0	8.0	25
	Growers Standard[3]	2.5		2.5	36
L.S.D. .05				1.7	13

* Months after initial treatment.

[1] Fertilizer incorporated in the potting medium just prior to potting on May 29, 1974.

[2] Plants topdressed with 20 lbs N/1000 sq ft on October 24, 1974 (5 months) and May 9, 1975 (11 months).

[3] 450 lbs N/acre/year (30 lbs N/acre applied 15 times during the growing season — fertigation).

Potted Liners in California. Potted liners of *Euonymus japonica* were planted in 1 gal cans containing 84% Douglas fir bark and 16% sand. Phosphorus, potassium, dolomite, lime, and fritted trace elements were added to assure adequate levels of secondary and minor elements. Various N sources were incorporated just prior to potting using 2 lbs of N/cu yd. The test was started November 11 with supplemental nutrients applied every 90 days to half of the plants and no supplemental feeding on the other half.

As shown in Table 5, when methylene urea was applied every 90 days the growth was superior to a single application at potting time. Plants treated with methylene urea (50% CWSN) were superior to plants treated with methylene urea (30% CWSN). A single application of experimental N sources varying in solubility compared favorably to a single application of methylene urea (50% CWSN) when a moderate release rate was evaluated (Exp. 3). As the release rate was reduced, a single application resulted in maximum growth when a very low soluble N source was used (Exp. 0.5). Growth was nearly doubled as compared to a fertigation program (1 lb N/1000 sq ft/week).

A repeat application of the experimental N sources 270 days after potting improved performance over single application at potting time when low to moderate soluble N sources were used (Exp. 1, Exp. 2, and Exp. 3). When the lowest soluble N source was used (Exp .05) a single application at potting time

Table 5. *Response of Euonymus japonica to methylene urea and certain experimental nitrogen sources incorporated in the potting medium*[1].

Percent CWSN	Nutrient Source	Solubility	Maintenance[2] Fertilizer (days)	Height (cms) (11 mo)*	Top Fresh Weight (gms) (16 mo)*
50	MU	moderate	0	26	78
50	MU	moderate	90	31	231
30	MU	low	0	25	48
30		low	90	36	179
	Exp-3	moderate	0	32	94
	Exp-3	moderate	270	34	160
	Exp-2	intermediate	0	35	155
	Exp-2	intermediate	270	40	180
	Exp-1	low	0	36	150
	Exp-1	low	270	40	205
	Exp-0.5	very low	0	38	228
	Exp-0.5	very low	270	41	231
	Control		0	18	12
100[3]		high	7	26	124
L.S.D. .05				6	35

* Months after initial treatment.

[1] Fertilizer was incorporated in the potting media using 2 lbs N/cu yd just prior to potting November 11, 1974.

[2] Fertilizer applied every 0, 90 or 270 days using 20 lbs N/1000 sq ft.

[3] 25-0-25, 447 ppm N (200 ml/gallon can/week or 1 lb N/1000 sq ft/wk).

provided maximum performance. The addition of the topdress was of no value.

Bare Root Seedlings in Ohio. Bare root seedlings of catalpa were planted in a 3/1 composted hardwood bark/sand mixture containing superphosphate and potassium sulfate. The plants were grown in the greenhouse at air temperatures ranging from 60 to 80°F. The equivalent of 2 inches of water was applied per week. Various sources of encapsulated N were incorporated in the potting media using the equivalent of 3 lbs of N/cu yd. Eleven weeks after planting, the catalpa was harvested for fresh weight determination. A second crop was planted using seedling catalpa in the 1 to 2 leaf stage. The second harvest was made 12 weeks after planting. No additional fertilizer was applied.

As shown in Table 6, N encapsulation dramatically increased safety as compared to urea. Catalpa planted immediately after incorporating the N sources were very responsive to treatment. Those formulations with a moderate release rate (Exp 4.6, Exp 4.0 and Exp 3.3) cause a setback in plant growth. Plants harvested from the second planting exhibited excellent development, however. Those formulations exhibiting intermediate low and very low solubility were very safe when incorporated in the potting media at planting time.

Growth was excellent on all treatments with less growth occurring at the intermediate release rate (Exp 2.8) and the very

low release rate (Exp 0.7) suggesting that these formulations were releasing N a little too fast and a little too slow, respectively, to induce maximum growth as realized with Exp 2.0

Table 6. Response of *Catalpa speciosa* to various experimental nitrogen sources varying in solubility.

Nutrient Source	Relative Solubility	Fresh Weights of Tops (gms) Harvest 1	Harvest 2	total
Urea	high	0	1	1
Exp-4.6	moderate	15	41	56
Exp-4.0	moderate	8	50	58
Exp-3.3	moderate	17	44	61
Exp-2.8	intermediate	27	41	68
Exp-2.0	low	56	39	95
Exp-1.7	low	46	33	79
Exp-1.1	low	40	38	78
Exp-0.9	very low	50	39	89
Exp-0.7	very low	21	52	73
Control		1	1	2
L.S.D. .05		8	7	15

[1] Fertilizer incorporated in the potting medium at 3 lbs N/cu yd.

[2] *Catalpa* harvested after 11 weeks (1st harvest). Pots replanted with *Catalpa* and harvested after 12 weeks (2nd harvest).

SUMMARY

Safety was dramatically increased by reducing the water soluble N level from 100% down to 75% or less. Maximum safety and growth from methylene urea was realized with 50% of the N in a cold water soluble form. In the midwest and northeast a residual of 4 to 6 months is realized while a 3 to 4 month residual is evident in more moderate climates (California).

Experimental N sources exhibited better residual and safety than methylene urea. This was particularly evident in moderate climates (California) with the trend still evident in the cooler climate of the midwest and northeast. A 12 to 18 month residual was realized with these experimental nitrogen sources.

MICROPROPAGATION OF *DAPHNE* × *BURKWOODII* TURRILL

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Abstract. A method for the rapid propagation of *Daphne* × *burkwoodii* is described involving meristem-tip culture, shoot proliferation, root initiation and transfer of plants to potting medium. The place of this method in a clean stock programme is described and results with *Daphne odora* are compared.

The virus diseases of *Daphne spp.* have been extensively studied by Milne and his students at Massey University (2). Three viruses were found in *D.* × *burkwoodii* and at least ten in *D. odora* cultivars. Nurseries in New Zealand need high-health propagating material free of known virus diseases and the New Zealand Nursery Research Centre in conjunction with the Plant Physiology Division has initiated a programme to produce this material. Last year the ways in which meristem-tip culture and thermotherapy might be used to produce high-health stock were outlined (1). In this paper the development of techniques suitable for meristem-tip culture of *D.* × *burkwoodii* to be used in conjunction with thermotherapy will be described.

MATERIALS AND METHODS

Young shoots of *D.* × *burkwoodii* were collected in late spring from two plants growing in gardens in Palmerston North. Micro-dissection and subsequent transfers were carried out under sterile conditions. Both apical and axillary buds were dissected using sterile needles and microknives made from thin chips of non-stainless razor blades held in a pin vice.

Media consisted of Murashige and Skoog (MS) salts (3) supplemented with myoinositol 100 mg/l, thiamin, 0.4 mg/l, sucrose 30 g/l and varying amounts of naphthaleneacetic acid (NAA) and kinetin (K) as indicated. Bacteriological Agar (Davis Gelatin Co., Christchurch, N.Z.), 6 g/l, was added to all media. Plastic petri dishes were used for the establishment of the cultures and early shoot proliferation and glass jars or tubes for further shoot proliferation and rooting of cuttings.

Incubation of cultures was carried out under a fluorescent light bank with an irradiance of 11 W m^{-2} PAR (about 2,500

lux) in a room maintained at 25 ± 2°C, with a photoperiod of 16 hours.

RESULTS AND DISCUSSION

Establishment of cultures. The shoot-tip, consisting of the meristematic dome and up to three primordial leaves, was excised and place on agar medium in a petri dish. The size of these explants was 0.2 - 0.5 mm wide and up to 1 mm long.

A series of 16 media with NAA and K at concentrations of 0, 0.1, 0.3 and 1.0 mg/l was tested. It was found that NAA was undesirable in the establishment phase, whereas K at 1 mg/l was most suitable. Within three weeks, shoots with somewhat thickened leaves up to 1 cm long developed on this medium (Fig. 1). If left on this medium, however, normal leaves rarely developed. The shoots were therefore transferred to a medium containing 0.1 mg/l NAA and 0.3 mg/l K on which one to several shoots with normal leaves and elongated internodes developed. Within four to six weeks these shoots had 15 to 20 leaves.

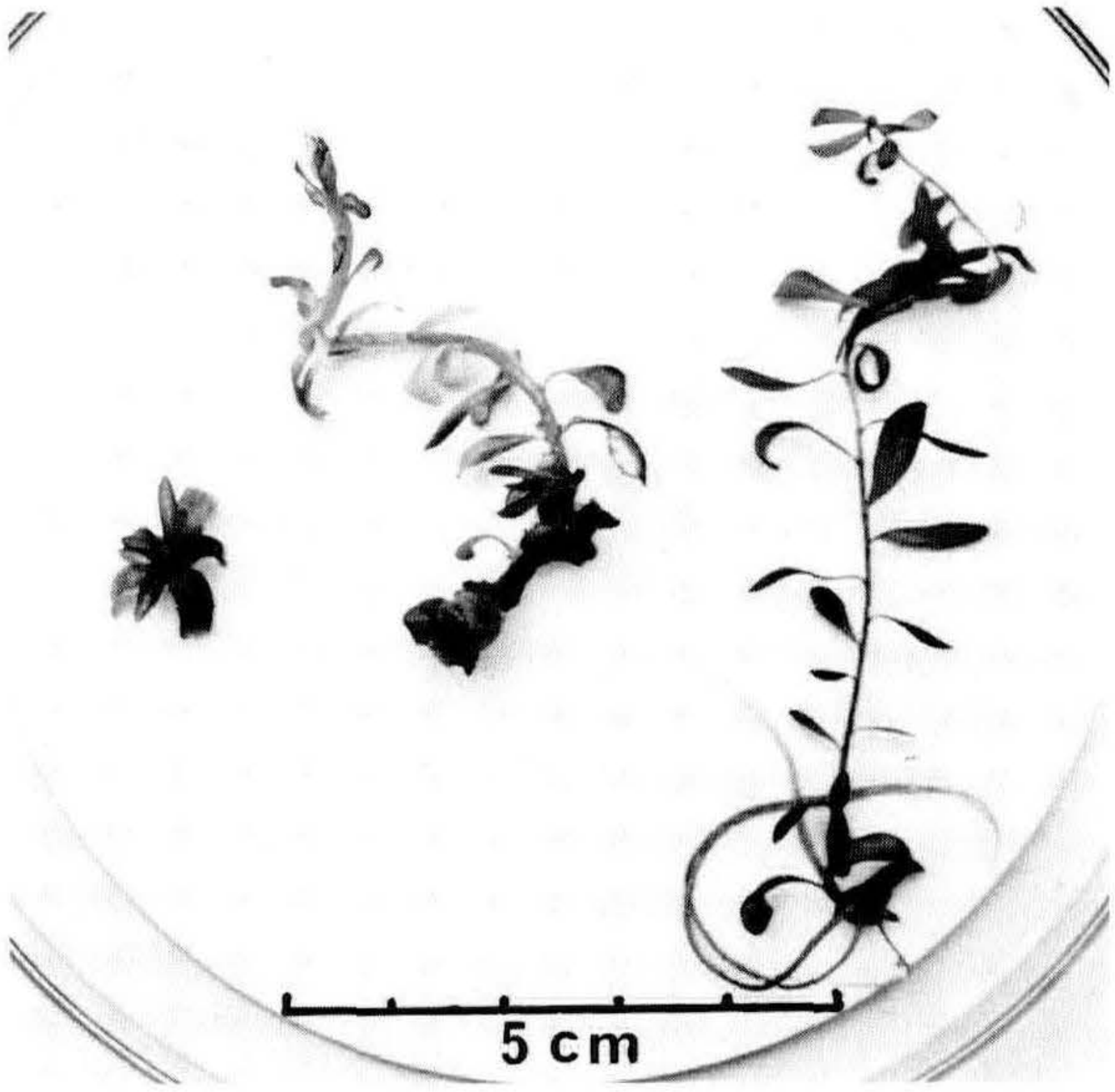

Figure 1. Stages in the micropropagation of *D* ' × *burkwoodii*.
Left – shoot-tip after 3 weeks on 1 mg/l K.
Centre – a single shoot growing from a 4-node section on 0.1 mg/l NAA and 0.3 mg/l K.
Right – rooted cutting after a tip section was dipped in 100 mg/l NAA and then grown on a medium without hormones.

Shoot multiplication. In order to increase shoot number, elongated shoots were cut into 4 node sections, then placed on fresh 0.1 NAA/0.3 K medium. New axillary shoots appeared,

usually from the upper nodes and each of these shoots was re-divided after a further four weeks to give 3 or 4 sections. On the basis of a 5-fold increase in 4 node sections per month, it would be possible to produce several thousand sections within six months.

Rooting of cuttings. Rooting of shoot-tips produced in culture proved to be difficult. Low levels of NAA were without effect, whereas higher concentrations induced callus and distorted roots which did not develop further. In order to induce normal roots, tip sections were dipped into a solution of 100 mg/l NAA in 50% ethanol before being placed on a medium without hormones; roots began to appear after three weeks.

Subsequent trials tested steeps in aqueous solutions of NAA at 100 or 200 mg/l for 5-60 minutes. A 10 minute steep in 200 mg/l NAA adjusted to pH 5.7 appeared to be satisfactory, and rooting has been induced in up to 7 out of 10 cuttings in some trials.

Transfer to potting medium. Great care needs to be taken during the transfer of plantlets from tissue culture, in which they are fed with a full nutrient medium under sterile conditions, to a potting medium in which they are exposed to a harsher environment and must rely on their own photosynthesis for sugars. When plantlets were transferred to Jiffy 7 peat pots and placed under intermittent mist, most of the plants died. A gradual hardening process was required. The procedure we have adopted has resulted in approximately 90% survival of the rooting cuttings.

The rooted plantlets were rinsed to remove the agar and were planted in Jiffy 7 pots soaked in a 0.3 ml/l solution of Terrazole (25% emulsifiable concentrate). The plants (and the Jiffy 7) were covered with an inverted 600 ml jar and placed under the light bank in the culture room. After about 4 days the edge of the jar was raised to reduce humidity and the plant was left for a further 3 days. The plants were then transferred to a propagating house with intermittent mist. After a further week, root tips were visible on the outside of the Jiffy 7 and the plants were transferred to a growing-on area in the glasshouse.

Health status of plants. Approximately 2/3 of the plants derived from shoot-tip culture of *D* × *burkwoodii* have been found to be free of rod viruses, using the electron microscope. Glasshouse-grown plants still infected with rod virus did not have any obvious virus symptoms. Since attempts to transmit this virus mechanically to the indicator plant *Chenopodium*

quinoa were unsuccessful (K.S. Milne, personal communication), the virus is probably Daphne Virus S. However, further tests are required to positively identify this virus and to ascertain whether other viruses might be present.

Work on Daphne odora. Parallel experiments have been carried out to ascertain the media requirements for *D. odora*. An auxin was required for the establishment phase and we found 1 mg/l NAA with 0.3 mg/l K was satisfactory, although growth of the shoot-tips was much slower than for *D.* × *burkwoodii*. After the initial establishment of *D. odora* shoot-tips, shoot growth was best on a medium with NAA reduced to 0.3 mg/l and 0.3 mg/l K.

Root induction on stem tip cuttings from tissue culture of *D. odora* 'Leucanthe' has been successful using the same procedure described for *D* × *burkwoodii*. To date, no indexing for virus has been done on shoot-tip culture derived plants of *D. odora*.

Problems. With *D. burkwoodii* the shoot-tip sometimes died and growth was then continued by an axillary shoot. With *D. odora*, the basal leaves on a shoot often senesced rapidly and the base of the shoot died. No cause has been found for either of these problems, but when they occurred green tissue was transferred to fresh medium and shoot growth continued.

The future. These techniques have already been applied to several daphne cultivars following thermotherapy. The first of the rooted plantlets from this experiment (carried out in conjunction with the N.Z. Nursery Research Centre) will shortly be transferred to Jiffy 7's. It is hoped that this experiment will yield a number of plants free of all viruses known to infect daphne species. If so, further plants will be propagated using rapid micropropagaiton techniques and will be released to the trade through the Nursery Research Centre.

Acknowledgements. We thank Dr. K.S. Milne for bringing the importance of virus diseases in daphne cultivars to our attention.

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A SIMPLE CONTROLLED ENVIRONMENT FOR SPORE CULTURE

FRED RUHL

Aqua Flora Limited, Mount Albert, Auckland, New Zealand

I don't wish to go into details of spore culture because every fern grower will have his own method, but everyone will also have experienced, to a greater or lesser extend, losses due to environmental fluctuations. From my experience I have devised a completely self-contained, controlled environment which ensured consistent and favourable results.

The "Contraption" as I call it, is made entirely from glass and resembles a miniature glass house. A conventional 150 watt aquarium heater and thermostat provide the heat and control. The size is determined by the dimension of the trays used. My unit is designed to accommodate two plastic seed trays and is constructed from 1/4 inch plate glass, the front being 10 inches high, back 15 inches high, by 40 inches long and 14 inches wide. The glass should be bought cut to size and glued together to form a tank. Small pieces of glass are glued to the middle of the bottom to form a cradle on which the heater is horizontally placed. A half-inch hole should be made in the top of the rear panel for the power cable leads. The glass cover should be in two or three pieces to facilitate easy access.

Having gone this far you can probably guess how the "Contraption" works, but before progressing further I would recommend sterilizing with Janola or salt. Sterilized clay pots are used as stands for the seed trays, plastic pots being unsuitable as they have the tendency to float around before one can place the trays. Sufficient water should be added to just cover the pots so that the trays are not in direct contact with the water. The thermostat is suspended just under the hole but well clear of the water. Condensation does not matter. The temperature will be determined by the particular culture. I have found New Zealand native ferns require 15 to 18°C while *Adianthus*, etc., do best slightly warmer, 18 to 24°C.

To start the culture I cover the "Contraption" completely with black polythene and, at the first sign of green on the medium, change the black for opaque polythene, and often also add a sheet of newspaper. As the first fronds appear, air should be given by lifting the cover a little at a time, increasing the amount slowly. The growth can be further stimulated by the use of Grow-Lux fluorescent tubes. From the onset it is impera-

tive that the strictest hygiene be maintained throughout and the water level be checked for evaporation.

After the prophalli have developed, fertilization takes place; this is the most critical period in the first stage of developing sporophytes. High humidity is essential for distribution of the sperms. The advantage of this system is that separate units can be easily constructed to provide individual environments which are essential because ferns have differing germination periods.

GRAFTING TECHNIQUES

A. MALOY

Lyndale Nurseries, Ltd.
New Lynn, Auckland,
New Zealand

As there are innumerable methods of grafting and each person has his (her) own preference, I will limit myself to the ones that I have used with some success.

Side Graft. We use this method to graft *Cedrus atlantica* onto *C. deodora* stock, also some hibiscus cultivars onto more vigorous stocks.

Prior to grafting, the rootstock plants are moved into the glasshouse to promote growth, usually up to 10 days before grafting. At the time of grafting, lower branches and side shoots are trimmed off and an oblique cut is made in the stock at an angle of 20 to 30°, up to an inch (25 mm) long.

The scion wood is cut into a wedge at the basal end, these cuts being made as smooth as possible. The scion is inserted into the stock while pulling the upper part of the stock backward, ensuring contact between the cambium layers. Once the top of the stock is released the scion should be held firm by the pressure from the stock. Then it is relatively easy to tie with raffia or rubber ties. The cut surfaces are then sealed with grafting wax, and placed in the area where they are to remain while the union heals. Once callusing of the wound is well progressed the stock plant is cut back by half of the amount that is above the graft. Then, once the grafts are well callused and prior to moving outside, they are cut right back to above the graft.

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Cleft Graft. We use this method to graft hibiscus cultivars onto vigorous rootstocks, camellia cultivars, also *Fagus* species.

In this case the rootstock is cut back to a suitable point for grafting, usually a part of the stem that is relatively free of large buds, and quite straight-grained. All shoots and buds below this point are removed with the knife. The stock is split down about 1 to 1½" (25 to 40 mm). The scion is cut in a wedge similar to the side graft and inserted into the stock with the cambium layers in contact. Again, the graft is tied and the cut surfaces waxed.

Approach Grafting. The distinguishing feature of this method of grafting is that two independent, growing, plants are grafted together. They can be growing in containers and brought into the glasshouse for grafting. It is a good method for grafting difficult subjects but, because of the trouble involved in bending down the scion wood and/or raising of the stock, and the gradual severing of the top of the stock and the base of the scion, it is probably not very economic. We have used this method successfully to graft *Tristania conferta* 'Variegata' onto *T. conferta* stock, after failing with other methods. The two stems to be joined should be approximately the same size. A slice of bark and wood up to 1" long (25 mm) is removed.

The cuts should be as smooth and flat as possible so that when pressed together the cambium layers will be in close contact. They are then bound together.

NEW PLANT MATERIAL OF THE GENUS METROSIDEROS

J.G. SHORT[1]

Victoria University of Wellington,
Wellington, New Zealand

The University maintains two small plant propagation units, one mainly concerned with growing plants for landscaping while the second unit is available for germinating seed and rooting cuttings of plants that are to be the subject of various research and demonstration programmes of the Botany Department. Some material comes to hand from time to time collected in the field by botanists who require a closer study of genera and species and who wish to have such plants propagated and grown on before they are classified.

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For some 12 years, we have been propagating and growing on plants collected by Dr. J.W. Dawson who has published a number of important monographs on the family *Myrtaceae*. In the course of this collecting work Dr. Dawson has sent back material from travels in the Pacific region, particularly from New Caledonia. Some of the *Metrosideros* species thus collected, after growing on in the glasshouse, have been planted out into an open shrub border and have been found to grow and apparently acclimatize quite well. Because of their relationship to our N.Z. Pohutukawa and Rata, we have had a source of comparison and find that *Metrosideros demonstrans*, one of the more successful of the new introductions, with its habit of growth and brilliant yellow flowers, makes a potentially very acceptable addition to the shrub collection.

METROSIDEROS AND THE PACIFIC REGION

We can well begin a discussion of this new plant material by commenting on the distribution of *Metrosideros* and related genera.

There are two main groups listed by Dr. Dawson:

(1) the Collina group which includes our *M. excelsa*, *M. robusta* and *M. umbellata*; some 26 species of this group are found also in the Kermadecs, New Caledonia, Fiji, Rarotonga, Tahiti, Hawaii and other smaller islands in the Pacific.

(2) the second group is made up of two sub-groups, one, related to *Mearnsia* and which includes the N.Z. *Metrosideros parkinsonii* and *M. fulgens*; and two the *Metrosideros diffusa* group which includes the N.Z. *M. colensoi* and *M. carminea*. The *Mearnsia* are found in the Philippines, New Guinea, Solomon Islands, New Caledonia.

In an examination of the distribution of the *Metrosideros* we find that in New Zealand they occur in our coastal and lowland forest while in the more tropical countries of the Pacific they often come from montane rain forests, which in part explains why we are having some success with acclimatizing some of the introduced species. Mountain regions where they are found in the Pacific Islands represent a sub-tropical or warm temperate climate not so far removed from the climate of the latitutides of northern New Zealand.

METROSIDEROS IN NEW ZEALAND

There are 11 species of Metrosideros native to New Zealand and this is the only country in which climbing species occur. We are all familiar with the Pohutukawa and the Rata of our forests but it may be suggested that there could be more interest shown in them for horticultural purposes. *Metrosideros parkin-*

sonii is named in memory of Sidney Parkinson, the draughtsman who accompanied Banks and Solander on Captain Cook's first voyage. His were the first drawings of our native plants to reach England. It is said that it was the inclusion of the colourful Rata family in his drawings which helped give a favourable impression of the trees and wild flowers of the far away Colony.

Legend has it that Maoris too were greatly impressed by their sighting of the northern shoreline of Aotearoa covered with densely flowering Pohutukawa. As they closed in on their landing place the Ranigitira of the canoe is said to have exclaimed "The head-dresses of this land are better than those of Hawaiki. I will throw mine into the water." The Pohutukawa was further elevated by them as they became settlers, and an ancient Pohutukawa tree growing on the northern extremity of New Zealand became the last earthly hand-hold of the spirit before leaping into the underworld. The Maoris, the navigators of the Pacific, found the Pohutukawa more attractive than the flowers of the lands they had left.

The *Metrosideros* species which I am discussing, and which have come to us from islands in the Pacific, incidental to their being studied for botanical purposes, will add I am sure to our interest in this attractive group of plants. It could lead to a greater interest in selecting better forms of our own species. We have experienced the growing of Yellow Pohutukawa from cuttings taken from tip growths of adult bushes, and this has led to the discover that they can be flowered as younger plants. There is a wide range of natural variations in the colour of flower and amount of flower produced by different plants of the Pohutukawa, and better cultivars should be selected if the species is to be displayed at its best in our landscape plantings.

Metrosideros carminea as a climber with its bright carmine mass of flowers could be used much more than it is. Grown from cuttings prepared from adult wood this plant will come into flower quickly, and when grown from such cuttings produces a bushy shrub suitable for growing in tubs. There are a number of variegated forms of *M. excelsa* and *M. kermadecensis*; there is a yellow-flowered form of *M. fulgens* that was found at Collingwood and there is the less well known but possibly most striking of all, *M. parkinsonii*. *M. parkinsonii* which will grow to a small tree of up to 20′ has bright crimson flowers. It was first discovered in the northern part of the South Island by Travers in 1882 and nearly 40 years later Dr. Oliver discovered it growing on Great Barrier Island, 400 miles away. This discontinuous distribution has been a matter of interest to botanists. Some difficulty has been experienced with propagating and growing this species for the garden, but the colour of

flower differing as it does from Pohutukawa makes it worthy of some effort in getting it established.

METROSIDEROS FROM NEW CALEDONIA AND OTHER PACIFIC COUNTRIES

Metrosideros demonstrans: Of those *Metrosideros* that form the new plant material to be discussed, certainly the most interesting to date is *M. demonstrans* from New Caledonia. It has a conspicuous inflorescence formed in the axils of bud scales just below a few pairs of foliage leaves and the terminal overwintering bud. The flowers are arranged in whorls of 3 to 4 which, when fully open, have more the appearance of the "bottle brush" of *Callestemon*. It makes a well-shaped shrub with bold foliage and has reached a height of 4 feet growing in an average garden environment. It has flowered for 3 successive years from October to November.

Metrosideros elegans: Also coming from New Caledonia, this is a taller growing shrub with similar yellow inflorescences but the flower is somewhat obscured by luxurious foliage. Plants of these are now 7 feet high and growing very freely in a sheltered position. They make very shapely shrubs, pyramidal in growth, and have potential as a tub plant. The leaves take on a wine-red colour in the cold weather of winter and so the tree is worth growing for its foliage effect alone.

Metrosideros collini: One plant of this species was doing well but was unfortunately destroyed during building construction. It had not flowered but a second plant survived its first winter. This species has slightly bronze-coloured foliage which, in texture and shape of leaf, is somewhat like our N.Z. *M. parkinsonii*. Coming from higher elevations in Tahiti, we may find that it will flower in open ground in New Zealand.

Metrosideros nitida: From New Caledonia is a low growing and spreading shrub which has flowers similar to *M. carminea*. It is of carmine-red colour with an inflorescence at the tip of the branches while the dark green leaves provide a background for the flower heads. A plant of this species has survived one winter outdoors and flowers toward the end of October.

Xanthostemon: Botanically, related to the above, are three different species of *Xanthostemon*, two of which have flowered in the glasshouse. When further plants of these become available, they will be moved out into the open ground. *Xanthostemon macrophyllum* has a very attractive flower with petals of cream colour and dominant yellow stamens. Its glossy foliage is also of note. *Xanthostemon flavum* has a striking pale yellow inflorescence, making a brush of circular outline at the tip of its branches and supported by strong textured leaves. *Xanthostemon aurantiacum* plants have not yet flowered.

Callistemon suberosum: Finally, and also growing under glass at present, is *C. suberosum* which has silver grey foliage which, in itself, makes this yet another plant from New Caledonia that we hope to try out further for its ability to acclimatize and grow under our garden conditions.

PROPAGATION

A number of the species described were received as plants directly from the field in New Caledonia. They were potted in a John Innes potting compost and held under quarantine in the glasshouse for their first years.

Cuttings have been taken from *M. demonstrans* and *M. elegans*; indications are that they will readily root from semi-firm tip growths planted in sand with bottom heat. Most of the work of establishing these plants has been from seed collected in the field. Seeds of *Metrosideros* and *Xanthostemon* have germinated readily when sown in the glasshouse on pure fine grained vermiculite and watered with a made up nutrient solution until sufficiently well established for potting on. By this means also they have been kept free of any damping-off fungi.

LITERATURE CITED

1. Dawson, J.W., Pacific Capsular Myrtaceae.
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3. Metcalf, L.J., The Cultivation of New Zealand Trees and Shrubs.

RAPID PROPAGATION OF POPLARS BY TISSUE CULTURE METHODS

H.C.M. WHITEHEAD and K.L. GILES

Plant Physiology Division
D.S.I.R., Palmerston North,
New Zealand

Abstract. A rapid method for the propagation of poplars by tissue culture has been developed. In comparison with conventional practices very large numbers of rooted plants can be rapidly formed from small explants and the potting mix can be manipulated to give establishment advantages to the tree when planting out. The technique also gives a method for the international exchange of poplar material under sterile conditions, to eliminate the danger of disease introduction, in a form that can be quickly bulked up at any time of the year.

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Because of the die-back and death of trees of many poplar cultivars in New Zealand due to the introduction of the rust

diseases *Melampsora laricini-populina* and *M. medusae*, large numbers of poplars planted for soil conservation purposes and timber must be replanted with cultivars resistant to these diseases. Large numbers of rust-resistant trees have been needed, therefore, to keep up with current planting programmes and replacement plantings. Many of these trees are newly-introduced disease-resistant or tolerant overseas cultivars, so there is likely to be a continuing need for large numbers of poplars of diverse origin for planting in many parts of New Zealand over the next few years.

Winton (1968) and Venverloo (1973) have shown that some species of poplar can be differentiated from callus cultures. The methods they describe do not offer a ready method for rapid propagation since the differentiation is slow and only limited numbers of shoots were formed on callus. This paper describes a method for the very rapid micropropagation of poplars by tissue culture.

EXPERIMENTAL

Axillary buds of *Populus nigra* 'Italica', *P.* 'Flevo' (*P. deltoides* × *P. nigra*) and *P. yunnanensis* were taken from either leafed or dormant branches. The buds were surface sterilized by dipping them in ethanol and flaming them, and then submersion in a 0.2% hypochlorite solution followed by several washes in sterile water. The outer bracts were dissected from the buds which were placed on a modified Murashinge and Skoog medium (1962). (Table 1). The medium contained the growth substances for medium 1 (Table 1). Cultures were maintained at 25°C with a 16h photoperiod and a total radiant flux density of 20 Wm^2.

Table 1. Composition of medium used for rapid micropropagation of poplar species. Modified from Murashige and Skoog (1962). Weights in mg/l.

	Inorganic nutrients		**Organic supplements**	
NH_4NO_3	1650 KNO_3	1900	nicotinic acid	0.5
$CaCl_2.2H_20$	440 $MgSO_27H_20$	370	pyridoxin-HCl	0.1
KH_2PO_4	170 H_3BO_3	6.2	thiamin-HCl	0.1
$MnSO_4.4H_20$	22.3 $ZnSO_4.4H_20$	8.6	inositol	100
KI	*0.83* $Na_2Mo04_2H_20$	0.25	lysine	100
$CuSO_4.5H_20$	0.025 $CoCl_2$ $6H_20$	0.025	sucrose	2000
FeEDTA	65.1 agar 1500			

Growth substances		
	Benzyl adenine	naphthaleneacetic acid
Medium 1	0.2	0
Medium 2	0.1	0.02
Medium 3	0.01	0.01

Bud break occurred within 2 to 3 weeks on medium 1, and within 4 weeks the axillary buds on the initial shoot had started to lengthen. The shoots were cut into 0.5 cm sections and re-

placed on medium 1. Adventitious bud formation and proliferation occurred on both cut and uncut surfaces, and existing axillary buds grew out. Once proliferation had started, tissue was transferred to medium 2 on which proliferation and growth continued for 6 to 8 weeks, after which time subculturing was necessary. Within this time 120 to 220 shoots had formed from each original bud explanted and some shoots had attained lengths of 6 to 8 cm. These shoots were then either rooted in pumice and peat or rooted under sterile conditions on medium 3 (Table 1). Root initiation under sterile conditions took place within 1 to 2 weeks. Alternatively these shoots could be cut into 0.5 cm sections and replaced on medium 1 to initiate another round of bud proliferation.

The results indicated that more than 10^6 plantlets per year could be produced from one bud of any of the clones used. *P. yunnanensis* gave more shoots than the other two clones used, and *P. nigra* 'Italica' produced the least number of adventitious buds. The plantlets produced initially juvenile leaf shape, but after transplanting into pumice:peat the mature leaf shape became established. After rooting, the plants were transferred to polythene sleeves containing the growing mix. The plants received half-strength Hoagland's nutrient solution whilst growing in pumice and peat. Within 3 months the trees were 1 to 1½ m tall.

DISCUSSION

The method of micropropagation described was rapid and gave large numbers of shoots from small explants of tissue. It has been shown to be effective with members of the genus *Populus*, section Aigeiros, and section Tacamahaca. Attempts are underway to see whether it can also be used to propagate members of the section Leuce. The method would be ideal for the rapid multiplication of new cultivars introduced from overseas since very large numbers can be quickly made available to Catchment Authorities and to those concerned with timber production. It has the further advantage that material can be exchanged internationally under sterile conditions reducing the risk of transmitting disease, yet maintaining the tissue in a state that allows rapid clonal propagation to begin immediately irrespective of the season.

The final product of propagation using this method is a rooted tree in growing medium. The method allows for the manipulation fo this growing medium to assist establishment in difficult areas. The height reached in a 3-month period after potting up, 1 to 1½ m, is ideal for the production of barbatelles. In this method the top is cut back to near ground level at planting and this allows for the establishment of a better root to

shoot balance. The method is commonly used in France and Italy and has been found to be extremely good in wind-prone areas, since the growth of the barbatelle *in situ* allows it to adapt to wind without the danger of wind throw.

Poplars for timber production are usually planted as 0/1 rooted cuttings, and equivalent specimens can be produced using the technique described here, provided a full season is available for growth prior to planting out. Production can be regulated so that rooted plantlets are potted up at the beginning of the growing season to ensure a supply of trees by the next winter.

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THE PROPAGATION OF DECIDUOUS AZALEAS

P. MARKHAM

Plant Craft Limited
Palmerston North, New Zealand

One of the most important aspects of propagating deciduous azaleas is the preparation of the mother stock. As time is the overiding factor, it is advisable to have stock plants containerized to ease handling.

During October, we move the stock plants into a glasshouse which has a day temperature of 18°C and a minimum of 15°C night temperature. Fluorescent lights are used to extend the day length to 11 hours. The stock can be re-potted just before being moved into the glasshouse but we have found that care should be taken not to damage the fibrous root system as this can cause collapse of the young shoots as they are forced into growth. Possibly the safest way to topdress the container is with a nitrogenous fertilizer, such as Uramite, 4 to 5 weeks before bringing them into the glasshouse. To further stimulate growth all flower buds should be removed without damaging the vegetative buds immediately below them.

The stock plants, held under the conditions described, show signs of vegetative growth in approximately one week.

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The stock plants, held under the conditions described, show signs of vegetative growth in approximately one week.

Once the buds have burst, growth is extremely rapid with sufficient material for cuttings being available in less than two weeks. If this sudden transformation from dormant to vegetative stage does not happen, look carefully at the day-length and temperature, as these both are critical.

At this early stage it is important that the root systems are healthy as the plants are being pushed hard to supply maximum growth. If the root systems are damaged through poor potting or soluble salts they will not be capable of supporting this growth. We have found that a mixture of 50% peat and 50% polystyrene is virtually impossible to overwater. The water is put on with a flooding nozzle until it is passing through the pot. It should also be remembered that the soluble salt concentration will be fairly high if the plants have been repotted or topdressed and even a small amount of drying will cause severe damage to the roots.

Growth on most cultivars quickly reaches 6 to 8 inches; it is at this stage that the shoots firm sufficiently to enable cuttings to be taken. Perhaps a better description of the growth would be "butter soft". If the wood is allowed to become too firm and reach a stage where it cracks when bent between thumb and forefinger the best stage has been passed and the cutting will take considerably longer to produce roots, if at all. I think that this judging of the correct time to take cuttings is the essence of the art of propagation.

When removing cuttings from stock plants we have found it advisable to retain at least two lateral buds, or new leaves, on the new growth, as it is from these buds that new shoots quickly develop. Once removed from the stock the cutting should be prepared and placed under mist without delay as desiccation is rapid.

We prepare the cuttings by leaving as much foliage as possible intact, removing only enough to give an adequate setting depth; the tip is not removed or the leaves reduced. A nodal cut is made and the cutting is wounded with a very sharp knife. The rooting substances usually used is Seradex 2. The cuttings are then set in a 50/50 peat, polystyrene mixture under mist with a base temperature of 20°C. The mist line should be checked to ensure that it is working correctly.

Rooting usually takes 3 to 4 weeks. The importance of correct wounding is obvious at this stage as without a wound the large fibrous root ball is often attached to the base of the cutting by a slender thread which is easily broken in the process of potting or lifting. Perhaps one way of overcoming this would be to root the cutting in a small peat pot or Jiffy container.

Once rooted we then tray up the young plants in a peat, polystyrene mix with nutrients added. The trays are then

placed under a weaning mist in a glasshouse to encourage the development of new growth. Anything that can be done to reduce handling of stock at this stage is advantageous, because if the young plants do not produce new growth before the onset of longer nights they usually fail to break the following spring. Once daylight hours drop below 11 hours per day young plants which have not developed new growth must be placed under lights. The temperature must also be carefully monitored at this stage, bearing in mind the maximum, minimums given earlier.

When new top growth and root systems have been developed, the trays can be moved out into shade houses for overwintering. Theoretically, it is possible to keep the plants in active growth through the winter months, thus producing cuttings throughout the year. This does work, but thought has to be given to supplying daylight extension to the propagating area.

If the plants are kept in full growth throughout the winter months, we have found that it's better not to move them out until November, to ensure that they stay in vegetative growth. If they are moved out earlier than this they can go into a dormant stage and stay this way until next spring. This poses another interesting question. Once dormancy has started can it only be broken after a pre-determined period of cool temperatures?

An alternative method of propagation is by seed. Seed capsules can be harvested during August or September and the seeds sown on a medium of peat and sieved spagnum moss. We add a small amount of fertilizer to our seed mix to encourage maximum growth before pricking out. The trays are covered with a sheet of glass and placed in a heated frame which has a base temperature of 20°C. Seeds of most cultivars germinate readily, although the orange and yellow types are, by far the most prolific. Seeds of reds tend to be shy in germinating.

The glass is removed immediately after seed germination but heat can still be applied to encourage growth. Once a fibrous root system has been formed, the young seedlings can be pricked out into pots or trays. As much growth as possible should be encouraged over the summer months to help the young plants survive the winter months. Light extension could be used to promote growth throughout the first winter if good growth has not been made over the summer.

THE PROPAGATION AND TRAINING OF STANDARD FUCHSIAS

J.S. WALLIS

Levin, New Zealand

PROPAGATION

In late February and early March cutting material was gathered from near the base of the standard ("tree") fuchsia plants. This basal growth tended to be more vigorous and sturdy and better suited to our requirements than top growth.

Tip cuttings of approximately 10 cm (4") long were made. The bases of the cuttings were dipped in Seradix II, before insertion in sharp river sand, with a bottom heat of 10° to 16°C.

It was found that no misting was necessary; a good watering 3 to 4 times per day was all that was required.

About two or three weeks later, roots were beginning to push and the plants were duly lifted from their rooting medium and potted into 3" fibre pots.

The potting medium was "John Innes" and consisted of 7 parts loam, 3 parts rotted leaf mould, 2 parts river sand. As there was a plentiful supply of fallen leaves in the autumn, rotted leaf mould was used in place of peat, with outstanding success.

The fertilizers added per cubic yard were: 2 lb superphosphate, 2 lbs dried blood, 1 lb sulphate of potash, 1 lb lime.

The soil mixture was fumigated with methyl bromide three weeks prior to using.

After potting, the fuchsias — in fibre pots — were placed in wood trays and well watered. They were kept in glass house conditions throughout the winter until early spring.

Fibre pots were used for two reasons:

1. The plants could be repotted without any root disturbance whatsoever, and
2. The roots could be allowed to penetrate and outgrow the pots without any detrimental effect upon the plants.

Regular watering and hygiene of plants included removal of fallen leaves, fornightly sprays of fungicide and insecticide, plus regular feedings.

TRAINING

The fuchsias were allowed to grow upright, keeping the terminal growth intact, but any side growths were pinched back to the first pair of leaves.

It was found that by keeping the main stem well clothed with foliage during the formative months, they ultimately developed a good strong stem, capable of standing on their own, sometimes without any other support. When a good root ball had developed, the plants were repotted into 6" clay pots and staked.

Winter temperatures in the glasshouse, not lower than 15° to 19°C, were maintained. In this way there was assured really good standard fuchsia plants by spring.

Tying of the plants commenced from the base and worked up the stem. As the plants grew, so the lower tie was being continuously removed and placed higher up the plant. Care was taken that the plants were not tied too tightly as a restriction could cause them to snap at the tie.

A strong main stem (well clothed) is first allowed to develop and then the plant is beheaded at the required height. In fuchsias the stems are rarely more than three feet in height.

Before the standard is "stopped" the final repotting is carried out. Great care must be taken when repotting from 6" into 8" clay pots (with the same potting medium and fertilizer base).

Upon "stopping", the liquid feed starts in earnest. Once a fortnight a foliar-feed type, e.g. Zest or Miracle Gro, as well as sulphate of potash (1 dessertspoon dissolved in 1 gallon of water), are used, e.g.:

7th of month	foliar feed
14th of month	sulphate of potash
21st of month	foliar feed
28th of month	sulphate of potash

When the standard is "stopped" the head commences to develop. The lateral growths push outwards and are pinched back at the second pair of leaves. Again the second growth from the laterals grows outwards and these are "stopped" at their second pair of leaves. From now on it is a continuous pinching back of each new flush of growth to the second pair of leaves, to develop the head.

All the growth along the main stem is now removed to allow the full intake of nutrients to go to the developing head.

A few early flower buds tend to develop but these are removed, until a good bushy head of sufficient size has developed.

About the middle of September, gradual "hardening off" is under way, the temperatures being gradually lowered.

It was found that as the watering and feeding was being eased down, that the roots of the fuchsias tended to grow into the porous clay pots. A sharp knife run down around the inside

of the clay pot was sufficient to prevent this happening.

By the middle of October, the standard fuchsias were transferred from the glass house to the shadehouse, and the final "hardening off" was in process.

Constant attention was still being paid to hygiene and cleanliness, with regular sprays of fungicides and insecticides.

During the first week of November, the plants were given a thorough soaking in preparation for removing from their pots and planting out into open beds.

SUMMER BEDDING SCHEMES

Standard fuchsias were used as specimen plants, under which bedding begonias were massed. They are also attractive for bordering a path, the same way that standard roses are employed. They may also be used as specimen plants throughout a display greenhouse.

About a month after the cutting material was gathered the standard fuchsias were lifted and stored in sawdust frames within the shadehouse over the winter period.

WHAT HAPPENS TO MY MANHOURS

WILLIAM ROGERS

Australasian Nurseries
Pakuranga, New Zealand

This paper is a description of a set of records I kept for a period of four years which helped me to go about my work more efficiently and make better use of my labor force.

I am the Production Manager of a container shrub unit attached to a mainly retail nursery. The production area covers about two acres and has turned out from 40,000 to 70,000 units a year of from 5-inch to 1-gallon sizes. I have a staff of 2 to 3 males and 2 females, mainly trainees. When I came to my present job ten years ago from growing house plants, the methods, soil mixes and so on were all new to me. The nursery was fairly new; the firm's outlines were set out but, in detail, were fairly sketchy. If one area of the nursery was under pressure we could be called on to help out.

It was felt after 12 months that productivity was too low, and I was encouraged to do some reading in management and work study. One of the main problems was to find out WHY we

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It was felt after 12 months that productivity was too low, and I was encouraged to do some reading in management and work study. One of the main problems was to find out WHY we

weren't turning out as much as expected. We were keeping monthly records of production bumbers, cuttings, pricking out, potting done, etc. Financial aspects were not my problem, but I wanted to know how much staff I was using and what they were spending their time on. This was tied up with other problems such as wastages — plant losses, knowing what the customer wants — when to have it ready, knowing growth, so one could produce the plants in the shortest growing period. These are all part of nursery efficiency and affect the manhours used. My immediate requirement was to find out just what people were doing and to see if I could improve the job from that angle.

I decided to keep hourly records. The first part was collecting raw material — what people were doing. We were using a sizable timesheet and were able to write down up to eight items each day if it was required. Jobs were recorded to the nearest quarter hour. This was reasonably accurate when people were doing bulk work, not so good when they were ducking off to do 10-minute watering jobs, making tea, doing small repair jobs or, in my case, answering queries. Staff wrote up their activities at the end of the day. It might take them a minute to do this. It took me half an hour a week to enter up on a weekly record. I make a 10% allowance for inaccuracies. It is often hard at the end of a day to remember exactly when one starts or ends a job. Major activities such as potting tend to be inflated, small jobs tend to disappear. I also "lost" the tea breaks about 1/16th of each day. However, the records did give me a rough but reasonable outline of how much time each of the major nursery activities was taking under our particular circumstances.

At the end of the week when doing timesheets, I entered the itemised manhours on graph paper under their headings. At first I had some difficulties with the headings, the job appeared so varied, but after six weeks I found which were repetitive, or parts of other jobs, and was able to reduce the number. I also began to find which jobs were occupying most time, areas of work to concentrate on. A boy might spend 4 hours a year hedge-cutting, but 10 hours a week potting. If the hedge cutting was a bit rough or slow, too bad; if the potting was poor or slow that WAS something to worry about.

The weekly record shows the main job headings. On the left is given a summary of the hours worked per person; on the right the manhours are analysed.

The third table is a quarterly summary of weekly activities. To visually find out where the time was spent I marked a square containing more than 10 hours per week with a coloured pen. This way I could pick out the problem areas more clearly for further study.

From the quarterly summary, as time went on, I made a further summary of these sheets. I spent many half-hours after dinner in the evening with the sheets going over the jobs, re-arranging them in my mind to see if I could organize them better. I will now go over a few of the jobs and discuss them in a little more detail.

Potting quickly showed up as the biggest time-consumer. The term, potting, as used here, covers a series of jobs from sorting and collecting plants, taking them to the potting bench, putting them in containers, pruning and staking if necessary, taking them to the standing area and watering in. It isn't an entirely standard process and has been altered from time to time as much as possible to speed the process, occasionally to fit round some obstacle. For instance, at one stage we took all the plants to the potting shed for potting, then took them to the potting area. Now in the summer when fine weather is fairly reliable, we collect all our materials near the standing area and pot there. It saves a lot of transporting to and fro.

Weeding. This is not a popular job and there is a lot of it; most of the staff is under 20, often temporary, such as schoolboys, After a lot of fighting over it, the boss wanting high standards, the youngest objecting to the boredom and backache, we find it most satisfactory to do four hours a day, preferably in the morning, in good weather, with the foliage dry. Everyone on it while we are fresh and then do something more varied and enjoyable in the afternoon. Rather than grumbling about missed weeds which gets me nowhere, I follow round checking each frame for odd weeds.

Soilmixing. We have an old chicken feed mixer — a third of a yard of mix at a time. At one stage there was the problem of who was to do it. This job to some extent depends on the people. I had one man quite happy prefilling bags all day long. Others on the staff weren't quite so enthusiastic; it is a bit hot and a bit heavy. It is partly a matter of taking turns, or having two on the mixer, particularly in hot weather.

Supervisory problems. This is time I spent on a variety of activities: planning, answering queries, getting advice, keeping records. At the beginning of the period I was spending a lot of time learning the job. I also had more staff, much of it very short term which meant more training, more planning, more supervision. Over the 4-year period the man-hours per year dropped from 10,000 to 8,000 for the same output of plants. Now my staff is less — and what I have — more permanent. I can spend more time on the job working with people individually, and as a pacesetter. The reduction in manhours is largely from schoolboy and short-term people.

This method of visual recording helps keep things in proportion. Problems that were looming large in my work seemed less disturbing when put down on paper, and the really time consuming ones were much more conspicuous.

Shifting. This heading covers the movement mainly of plants from one area to another, without other work being done to them such as potting. It is often not productive, and at the beginning of the period took quite a lot of time. Sitting down occasionally and making lists of plant movements can help cut out unnecessary shifting. For a while we did some of the warehousing — preparing plants for sale. The number of times a plant is handled from the time it is selected in the production area to the time a customer selects it is at least six to eight. These movements are: selected from production frame, taken to road, weeded and staked if necessary, labelled, put into trailer — taken off in sales area and put in frame — selected by customer. If things aren't going well quite often the movements are more convoluted than that. The movements within the production area dropped from 150 manhours to 75 over a period of four years. This was partly due to improved equipment, we went from an old 15 cwt truck which involved a lot of heavy lifting and carrying to low trailers which could be maneuvered to the exact spot of handling.

We also examined procedures. In the middle of summer some small stock was put in a shade house then after a month, when it was established, shifted outside. Now it is put straight outside with a few taller plants dotted through it to break the wind and the sun. Frost-tender stock, when potted in the autumn, goes straight under frost control sprinklers. Fast growing stock in summer is spaced slightly when putting down, so it doesn't need rehandling. I try to train staff to think in terms of minimum handling. If they are not well organized, people can work hard and yet get little done. I try to make them think first, so that they can get through a lot with minimum effort.

Hand-watering. We have an automatic watering system, but in dry periods there are always a few plants that dry a lot faster than the rest. From October on, we try to keep grown stock between two sprinklers. It can often be worked while clearing frames for potting so a special effort isn't required. Getting plants well under sprinklers takes only as long as one hand watering, and we always have an extra check round before the Christmas holidays, when we are likely to have sketchy and untrained staff which makes the job very slow. I try to have as little overgrown stock through this period as possible, seeing what is kept is pruned or potted where necessary. We try to keep hand-watering down to three times weekly and to as few lines as possible.

Some jobs such as feeding-topdressing the containers at four to six weekly periods haven't shown much improvement. We did examine prills at one stage, but they didn't seem to fit into our programme. With three to six monthly feeding periods with mixed stock, some stock was likely to be missed, other stock getting too much too soon.

Cuttings. We set daily targets of 2,000 cuttings for four people, about 28 manhours, then see how near they get to it. This includes collecting, making, planting, putting away and records. Time taken varies with the kind of cutting and experience of the worker. Knowing what to grow and when, with concentration on hygiene, are big helps here.

Pricking out. We used cardboard sections (Dividers) rather than 3″ pots. This job is fairly routine. Two ladies can plant 1,000 rooted cuttings a day into divider boxes provided rooting is even; there is not much replanting of unrooted cuttings, and the roots don't have to be trimmed because they have got too long. Seedlings at the right stage can be handled much faster. It is a matter of acting promptly, and doing the job regularly once a week, so the roots don't get out of hand.

Some of the jobs, such as "picking over" are routine tasks. It has to be done daily. It is done in the minimum time, for us not more than half an hour on Mondays, quarter of an hour the rest of the week. Restanding plants after winds is an irritant. We use corrugated fibrolite, which is good for drainage and hygiene, but not so good for taller stock. Having plants grouped together or roped around helps. Cold frame opening takes time during the frosty months. How much time and when? These jobs are not big time users but take manhours away from the more productive tasks.

To sum up. Much of the value of the record-keeping was in short term comparisons. We potted 800 plants into gallon bags in 60 manhours — could we do the same again next time. We did the weeding in 80 hours; could we keep it up? If not, why not — if it was better why was it better? Jobs were often broken up between weeks. These records helped to reassemble the hours put in. Over a longer period it gave me a picture of where the bigger proportions of time were going. It also helped me to use staff better. People, particularly boys, get tired of weeding for long periods, and also sitting, making cuttings. They want to try these jobs out, but half a day at a time.

Since I discontinued the full detailed list of work done, I have kept a sheet of weekly manhours per person. This compared with monthly production totals, plus background knowledge of where the time is going gives me an adequate idea of whether we are being less or more efficient for our circumstances.

INNOVATIONS IN PROPAGATION HOUSE CONSTRUCTION

W.L. VAN DYK

Duncan & Davies Limited
New Plymouth, New Zealand

Three years ago we commenced relocating our main propagation department from the present site in New Plymouth to our 176 acre production nursery 10 miles north. This was to be completed in three stages. Stage 1, which consisted of 8,000 sq ft was completed 2½ years ago. Stage 2, of an additional 10,000 sq ft is now operative.

The old propagation department is largely made up of glass, rigid type plastic structures, and polythene houses of a variety of shapes and sizes built over a period of 70 years. The cost of re-building in glass was prohibitive so we decided to seek a cheaper substitute for our million plus cutting production per annum. Plastic with it's low level of capital investment seemed to be the best alternative.

The Lee Valley Experimental Horticultural Station started work on film plastic structures in 1968 and has largely overcome the resistance to plastic tunnel developments. We based our design with modifications, on their prototypes as described in Station Leaflet No. 17 and No. 20. There are many differences between the use of glass versus plastic film, and as previously mentioned the main one is cost. The annual cost of re-sheeting a polythelene house amounts to approximately the same as the annual labor cost of cleaning glass! The lightness of structure requires fewer supports and although plastic transmits heat rays more effectively than glass and is colder in winter, heating costs are similar because of the relative airtightness of plastic structures.

With rapid advancement of technological changes and new materials the use of plastics allows greater flexibility. A grower would think twice before replacing an acre of glass with a substitute material.

Stage 1 consisted of 4 separate polyvinyl chloride (P.V.C.) houses 100′ long and 20′ wide; 3/4″ diameter (1″ in later structures) galvanized pipe frames 4′ apart supported the plastic. Bed heating was supplied by thermostatically controlled electric cables embedded in a concrete slab. Each house holds from 50,000 to 100,000 cuttings.

I will discuss some of the various changes and innovations which we have made in Stage 2 of the project.

COVERING MATERIALS FOR PROPAGATION HOUSES

P.V.C. – (12 gauge). The covers of the first four houses are still in a reasonable condition after 2½ years of use and will last for the expected 3 years.

Present cost for a cover 100′ × 32′ with 4″ pockets for rope fixing is approximately $570.00.

Polyethylene Film (5 gauge) — Last for a year under our conditions and present cost for a 100′ × 32′ sheet with pockets is $175.00.

Ethylene Vinyl-Acetate — E.V.A. Unfortunately we have not yet covered a house in E.V.A. but results in the U.S.A. and Europe have proved the durability of this film with it's more elastic, anti-fog and anti-dirt properties. Costs are 1/4 cent per sq ft more than polyethylene.

Reducing Poly-Cover Degradation. Where polythene comes into contact with the galvanized pipe frames 'hot spots' occur, causing breakdown of the film.

We are engaged in trials with painting 4½″ wide protective strips of an acrylic paint over the outside of the film. This will be compared with our traditional method of sleeving the 1″ galvanized pipe with shade cloth.

Double-Skin Houses.

	Heat loss: Btu ft² °F/hr	
Material	**Single Skin**	**Double Skin**
Polythene	1.6	0.8
P.V.C.	1.4	0.5
Glass	1.25	—

Heat loss by convection and radiation calculated by Walker & Cotter (*Acta Hort.* 6:26-46).

Trials are in progress with P.V.C. and polyethylene doubleskin houses. An insulating layer of pressurized air created by a continuously running blower separates the two sheets. As can be seen by the above table we hope to save costs of heating due to the improved insulation which is very important with recently announced fuel cost increases. There will be some reduction in light transmission and in ventilation requirements in hot sunny weather.

Sunclear. This American anti-condensate spray has proved very effective on preventing water globules from falling onto cuttings. A film of moisture is formed on the inside of the cover and there may be some reduction of heat loss which occurs through the air spaces between the water droplets.

Environmental Controllers. Instead of the mass of thermostats and individual controls used in the past, we decided to incorporate the following for each propagation house into one control unit cubicle:-

1. *Cooling*	Staged control of two 24" fans.
2. *Air heat*	Control of a 50,000 Btu gas-fired blower.
3. *Floor Heat*	Control of two halves of the propagation house floor.
4. *Misting*	Calibrated control of two separate 230 VAC water solenoids by a sensing element with an adjustable time control from 0 to 10 seconds.
5. *Provision*	For the future addition of two controls, e.g. CO_2

The control units incorporate a siren and visual lamp indicationg for high and low temperature extremes and mist failure which would cover sensor, fan and heater faults.

We are finding that although this control equipment is complex and initially expensive at approximately $1,200/ cubicle, it's use is highly desirable both to obtain the correct environment and to effect the maximum economics.

Floor Heating. Comparisons were made a year ago of the relative costs of the various heat sources and are not necessarily at the current rates.

Heat used Prop. House/hr.	**Fuel amount used**		**Unit Price**	**Running cost of heat used**
100,000 Btu	Electric	29.3 Kw/h	0.97¢ Kw.h	28.42 cents
100,000 Btu	Gas	1.33 therms	12.0¢ therm	16.0 cents
100,000 Btu	Oil (diesel)	0.8145 per gallon	35¢ gallon	28.5 cents

The above is based on 1 kw = 3412 Btu and that electric heating is 100% efficient compared to gas and oil having an overall efficiency of 75%; i.e. 100,000 Btu heat used in propagation house = 1 therm used in propagation house = therms of gas used by boiler.

Data received from various sources showed that alkathene piping used in the beds would make a cheaper alternative in material and laying costs than steel pipes.

Although the capital costs for the hot water system (120°F) versus electric cables was 25% higher it was estimated that the lower running cost would soon re-coup the difference.

CONCLUSION

Although "actual" costs are still to be calculated for Stage 2 of the project we feel that we are stepping in the right direction as far as type of construction and materials used. Even in the relatively short time of 3 years many changes have occurred in the horticultural equipment field. Who knows how Stage 3 will develop?

DESCRIPTION AND PROPAGATION OF THE NEW ZEALAND SOPHORA SPECIES (KOWHAI)

G.N. GOLDIE

Horticultural Research Centre
Research Division
Ministry of Agriculture and Fisheries
Levin, New Zealand

The Kowhai, pronounced by the Maori, kor-f-eye, means yellow and this is most evident throughout both islands from August to November when plants of this genus burst into flower often on sparsely-leaved branches, according to the species and district. Some overseas visitors have referred to the Kowhai as the New Zealand laburnum while many enthusiasts have proposed that it should be the national flower. The golden, drooping flowers, symbolic of spring, provide abundant nectar and pollen for such visitors as the tui, bellbird, kaka, silver-eyes, bees, butterflies and night-flying moths. No wonder the Kowhai never fails to gain the admiration of the horticulturist or of anyone who appreciates the beauty of nature.

The following descriptions and comparisons within the New Zealand genus should help to clarify some of the uncertainties that may have existed in understanding the Kowhai.

The genus *Sophora* (from sophera, an Arabic name for some leguminous trees), is not confined to New Zealand, there being some 38 species scattered throughout Asia, North and South America, the north-east of Africa and Australia, also on islands of the Pacific, Indian and South Atlantic Oceans. The New Zealand species of *Sophora* are not very well defined and

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at present there are 3 species, 2 botanical varieties and 1 cultivar.

They are:

S. microphylla
S. microphylla var. *fulvida*
S. microphylla var. *longicarinata*
S. prostrata
S. tetraptera
S. tetraptera 'Gnome'

Undoubtedly in the future other types and forms of interest to the nursery industry will become available from a collection of *Sophora* ecotypes which Dr. E.J. Godley, Director of Botany Division has established at Lincoln.

Sophora microphylla could be termed the common kowhai. It grows to 10 m high and is distributed throughout both islands from near North Cape to Southland and on Chatham Island from sea level to an altitude of 700 m.

It is within this species that so much variation occurs. It has been postulated that this diversity may indicate a relatively recent hybrid origin of this species, the parents probably being *S. tetraptera* and *S. prostrata*. Though today these two species do not occur naturally together, they could well have done so in the past when both the North and South Islands were joined during the glacial period.

The juvenile phase of *S. microphylla*, which has been reported to persist from 10 to 17 years, has been a limiting factor in the extensive propagation by nurserymen of this species from seed. The dense bushy stage with divaricating branches and small leaves could well be the expression of *S. prostrata's* character in different degrees in *S. microphylla's* hybrid origin. Besides this juvenility factor *S. microphylla* can be distinguished from *S. tetraptera* in that the former's leaflets are usually less than 10 mm in length, the flowers are generally of a richer colour, the standard being about the same length as the wings and distinctly notched at the tip. Because of its variability *S. microphylla* exhibits a diversity of flowering times in different regions and can be found in full bloom as early as July through to November, depending upon the season. *S. tetraptera* bloom is usually confined to the months of October and November according to district and climate. Finally, *S. microphylla* is considered to have a more robust nature that commends it to the horticulturist.

The two varieties of *Sophora microphylla* (var. *fulvida*) and (var. *longicarinata*) both fail to exhibit the juvenile form found in the species *S. microphylla* and grow straightaway into small trees of 3 m and 4.5 m respectively, making most attractive

trees for the small garden. *Sophora microphylla* var. *fulvida* is found naturally on the coast west of Auckland and in the Wanganui River catchment. It is quite distinct from all other Kowhais, the leaflets being 2 to 4 mm long while the flowers are among the largest of the native sophoras. It is not dissimilar to *S. tetraptera*, the standard being shorter than the wings and the apex entire, or only slightly notched. The flowers have a tendency to hang more or less upside down like those of *S. prostrata* but not so markedly. Flowering is from mid-October till mid-November, 7 to 8 years from seed.

S. microphylla var. *longicarinata* is found naturally in the Takaka district northwest of Nelson, growing in practically pure limestone country. It has leaflets almost as small as *S. prostrata* but has a slender habit which gives a very airy appearance. The flowers are pale yellow in colour 44 mm long, slightly larger than typical *S. microphylla*, and the standard is distinctly erect as compared with other New Zealand sophoras. This variety with its delicate graceful weeping habit could well be grown more widely in the small home garden.

S. prostrata is found between Blenheim and the Waitaki River on the lowlands and hills of the eastern South Island and forms a low rounded hummock bush 1/2 m in height with densely intertangled orange-brown rigid branches. Sparse, hidden flowers are 25 mm long of predominantly orange colour which are usually upside down due to the twisting of the stalk. The leaflets are small and sparse but at no time considered deciduous. In cultivation this species proves to be very hardy and could be used in rockeries and there may be limited use for hedging when more erect forms are selected.

Sophora tetraptera, the east North Island kowhai, wrongly named *S. grandiflora* by some nurserymen, is found naturally from East Cape down through Taihape to the Manawatu Gorge and as far south as Carterton. It is a small to medium-sized tree of approximately 10 m, thriving around forest margins, lakes and rivers from sea level to 450 m. The branches are drooping and spreading. The leaflets differ from all other New Zealand sophora species in that they are larger, being 3 cm long. The large pale yellow flowers produce wings that are longer than the standard, which is entire or only slightly notched at the tip. The species does not have a juvenile form and can be expected to flower in 4 to 5 years.

The only present cultivar in the New Zealand genera of *Sophora tetraptera* is 'Gnome', a deciduous shrub 1 to 2 m tall, which has only been available since 1974 through the nursery trade. Plants, 30 years or more in age, are growing in Christchurch Botanic Gardens and others, 25 years plus, at Otari Plant Museum, Wellington. This cultivar is an erect stiffly branched,

deciduous, bushy shrub with main stems rising in stool formation. There is no divericating juvenile form and plants of two years of age have been known to produce large yellow-tinged green flowers 6 cm long and, like the species *S. tetraptera*, the leaflets are 3 cm long. Flowering of this dwarf kowhai which appears to be tremendously hardy can be enhanced by the removal of the soft terminals of the main stems giving an abundance of flower in the following September and October, making it an ideal shrub for the small garden.

The time-honoured method of propagation of kowhai has been by seed. Some propagators collect the seed when just ripe and sow immediately so that the testa or seed coat has not had time to harden. Others have collected later in the season and soaked the seed in hot water for 24 hours or broken the hard testa by chipping or filing opposite the micropyle. All these methods have been successful except in the case of the cultivar 'Gnome' which appears to have a very soft testa; the hot water treatment destroying germination completely. However, excellent germination can be obtained in 10 days under mist with bottom heat of 25°C.

Vegetative propagation involves no change in the genetic makeup of the new plant with the exception of mutations. Many nurserymen take advantage of this fact when making their selection of stock plants which, in many cases are, or should be clones. Until recently the kowhai has been grown almost entirely from seed. The need for standardization of plant material for sale in New Zealand and for export has made a study of vegetative propagation of this genus most important. Also, the public demand for instant results in the beautification of their home surrounds has placed pressure on the nursery trade to supply predominantly plants which will give a display early in their life.

Sophora microphylla, with its juvenile phase persisting from 10 to 17 years, has been placed in the "cinderella" class by the industry. With this in mind, the Horticultural Research Centre, Levin embarked on a project with the object of obtaining precocious flowering by propagating from adult growth in *Sophora microphylla*. To date we have found that the adult form can be propagated vegetatively from cuttings in mid-November. New growth, 8 to 10 cm long, was taken with the tips nipped out and with a single wound opposite the basal bud. Cuttings were given a Benlate dip (0.5 gms per litre), treated with Seredix No. 2, then inserted into 50/50 peat/pumice mix in a closed frame with mist and bottom heat of 25°C. This gave 100% rooting in 14 weeks. Over a period of 22 months, the plants have just entered their second spring. Growth has averaged 1 m, the plants being well feathered from the base and

approximately 2% have produced flowers. This should substantially increase in the third season. Plants have been staked in their PB3's to encourage upright growth in this initial stage. This may be an important factor when growing S. *microphylla* from adult wood because when naturally grown plants attain their flowering stage they lose the divaricating form and develop a rounded leafy head with branches spreading and drooping from a naked trunk which has been initiated in the juvenile stage. By propagating from adult wood, plants could be of lax drooping habit without a trunk unless staked in the initial stage of growth.

Within this project of vegetative propagation the Research Centre has found that 1 year S. *microphylla* seedlings can be used as stock for chip budding, side and veneer grafts without the reversion of the adult scion wood to the juvenile form. The former chip budding gave only 50% take; this could well be improved with better techniques. This method of vegetative propagation could well be kept in mind, especially where scion material is difficult to obtain. With regard to the remaining 2 species, 2 varieties and 1 cultivar mentioned earlier, these also have responded most favorably to the cutting technique we adapted for S. *microphylla*.

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EARLY RECORDS OF PROPAGATION TECHNIQUES FOR AUSTRALIAN NATIVE PLANTS

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In recent years improved selections and a few hybrids of Australian native plants have appeared in the nursery trade as well as an increasing number of species. However, these are still very few compared with the enormous number of native species with ornamental value.

Many apparently little known species are being grown only by specialist growers such as members of The Society For Growing Australian Plants. This same Society has been and is very active in all states in furthering an interest in use of indigenous plants in parks and gardens.

One of the more obvious results of this interest is the Canberra Botanic Gardens which is, I believe, the only botanic gardens in the world devoted exclusively to its continent's indigenous flora. I should mention also Maranoa Gardens and the extensive use of natives in airport and freeway plantings in Melbourne, the specialist gardens such as Stony Range, Kuring-gai Wildflower Gardens, and Bankstown Wildflower Reserve in Sydney and nearer at hand, the plans for extensive use of native plants in the development of the Brisbane airport.

There would appear to more interest now in cultivation of Australian plants than ever before, so it is interesting therefore, to look at the record and see just what has happened in times past.

The oldest publication about the cultivation of Australian plants that I have been able to locate is titled "*A Specimen of the Botany of New Holland*" and it is quite astounding to realize that it was published in 1793. In his preface the author, James Edward Smith says, "The present work must be considered only as what it pretends to be, a specimen of the riches of this mine of botanical novelty". The book contains 16 beautiful paintings by James Sowerby. Two of these are *Styphelia tubiflora*, and *Goodenia* (now *Scaevola*) *ramosissima*.

Curtis' Botanical Magazine commenced publication in 1787. Its correct title is "*The Botanical Magazine of Flower Garden Display*". Under the title it says, "in which the most ornamental foreign plants cultivated in the open ground, the

[1] District Advisor in Horticulture

greenhouse and the stove are accurately represented in their natural colour, to which are added their Names, Class, Order, Genus and Specific Characters according to the celebrated Linnaeus, their places of Growth and times of flowering, together with the most approved method of culture".

Curtis' Botanical Magazine was not confined to Australian plants of course, and the first Australian plant was included in Volume 4, Plate 110. It was *Mimosa verticillata* "flowering in 1790 . . . introduced from New South Wales to the Royal Botanic Gardens by Sir Joseph Banks". Next in Volume 6, Plate 260, published in 1794, was "*Metrosideros citrina*" or, as we know it, *Callistemon citrinus*.

"*Flora Australasica*" by Robert Sweet was published in 1827-28. The full and somewhat wordy title is "Flora Australasica, or A Selection of Handsome or Curious Plants Native of New Holland and the South Sea Islands".

The illustrations by E.D. Smith are entirely from specimens in cultivation in England. Mr. Sweet's book contains plates to 56 species and along with other information, "a full account of the best method of cultivation and propagation". I will quote a sample from this remarkable book: "*Correa pulchella* . . . Seeds of this handsome species of *Correa* were collect by William Baxter, the indefatigable collector of F. Henchman Esq. at Kangaroo Island on the south coast of New Holland; from those were raised young plants in 1824 at the nursery of Mr. T. Mackay at Clapton where they began flowering for the first time in February last; and plants of it are now for sale at his establishment where many other new or rare plants from New Holland have flowers this season and others are continually coming into bloom."

A quote from Mr. Sweet's dissertation on *Epacris impressa* will illustrate the type of cultural information that he detailed. "The plants of this genus succeed well in a light sandy peat soil; or when grown large a small proportion of light sandy loam may be added to it. When young, they require to be in small pots and to be shifted into larger ones as they increase in size; the pots should be well drained with potsherds broken small as the roots are fond of running amongst them and the earth will not become sodden which it is otherwise very apt to do; this injures the plants very much; another thing which often proves fatal to the plants of this genus is their being placed in a situation where the sun shines full on them, when set out in the open air in summer; their roots always grow around the pot on the inside and they are so very small that the sun shining against the pot scorches them and entirely destroys them and it is a chance if the plants ever recover. Young cuttings planted

under bell glasses in sand root readily; the autumn is the best season for putting them in."

Mrs. Loudon's comprehensive volumes "*The Ladies Flower Garden*" were published between 1840 and 1843 in five parts, one on Ornamental Bulbs, one on Ornamental Annuals, two on Ornamental Perennials and the last on Hardy Greenhouse Plants. It was by no means confined to Australian plants, but if you have the time to read through the text, a large number are included in each of the sections.

There are many other fascinating publications too that contain items about the culture of Australian plants: Some are of enormous length such as "*The Gardener – an Illustrated Weekly Journal of Gardening in all its Branches.*" It extends from June 1872 to January 1902.

By the 1880's it would probably be fairly safe to say that practically every Australian plant with some ornamental potential had been tried, and when "*The Illustrated Dictionary of Gardening,*" appeared during the 1880's it listed, with cultural details, well over 1200 species of Australian plants as well as some 60 other genera without delineating the species because they were considered "lacking popularity or virtue". It had, in fact, sorted out over 1200 species of the best of the Australian plants.

This monumental publication "The Illustrated Dictionary of Gardening — a Practical and Scientific Encyclopaedia of Horticulture for Gardeners and Botanists" was published in four volumes, between 1884 and 1889. A Century Supplement followed later in 1900.

I never cease to be astounded every time I leaf through the pages of this magnificent publication at the exhaustive list of what we would call little known Australian plants for which cultural details are given. Some of the unusual plants listed include *Pachynema* (from Northern Territory), *Amorphophallus* (from Northern Australia), *Fieldia* (a relative of gloxinia from our high border rainforests), *Myrmecodia* (one of our tropical Ant House plants), and *Cephalotus* (one of our pitcher plants).

Other tropical Australian plants detailed include *Cerbera* (the "true" native Frangipanni), *Cochlospermum*, *Dolichandrone*, *Pandanus aquaticus* and *Faradaya splendida*.

The surprises include *Decaspermum*, *Trochocarpa*, *Helmholtzia* (now *Orthothylax*), *Medichosma*, *Eupomatia* — the list is seemingly endless. It includes some plants that I thought nobody had noticed or grown except me.

Rhododendron lochae, our only Australian rhododendron, was drawn to our attention in the December 1961 issue of Au-

stralian Plants, "Romance and the Rhododendron"; but it was in cultivation in 1887.

Orthosiphan stamineus (now *O. aristatus*) was released in 1974 by Queensland nurserymen with a successful publicity campaign, "The Cat's Whiskers"; it was well known in 1869 as "The Cat's Whiskers".

I have been very proud of a few plants of the lovely pink *Podolepis gracilis* that I have grown over the last 2-3 years. Few people here known it. However, the Dictionary of Gardening in 1857 rates it as an outstanding annual and Mrs. Loudon illustrates and commends it in her 1840 book on Ornamental Annuals. She says "the seed may be purchased in any seed shop".

Australian ferns are well covered in these early writings as well as very detailed methods of successfully raising them from spores.

Grafted plants of a *Brachychiton* have been available here in a small way for some years, as well as a grafted selection of *Ceratopetalum*. A number of other native species have been grafted within such genera as *Banksia* and *Eucalyptus*.

Certainly grafting and budding offer interesting possibilities in overcoming problems such as root rot susceptibility and propagation of outstanding forms. However, apart from fruit trees, roses and, in the southern states, a few conifers and deciduous plants, very little of this skill is practiced here.

No doubt it could be argued that present day labor costs prohibit such a labor intensive, high unit cost method of propagation. However in England at the present time, the greatest importance is placed on highly selected forms and the majority of trees and many shrubs are grafted.

Grafting of Australian plants was practiced quite extensively during the early part of the 19th century, particularly in regard to *Correa*, *Boronia*, *Crowea* and *Eriostemon*. All these genera were grafted onto roots of *Correa*, mostly *C. alba*. The Dictionary of Gardening said in 1885 "by employing this mode of propagation the better kinds grow more freely and useful sized specimens are produced in less time than by use of cuttings". *Pittosporum* was among other genera propagated by grafting.

Let us then look at some of the other notes on propagation. For instance, under *Trichinium* (which we now know as *Ptilotus*) the following, "Propagation is readily effected by means of the thick roots which should be cut into pieces about 1 inch long and inserted in sand in bottom heat".

The propagation instructions given in The Illustrated Dictionary of Gardening were fairly standardized and somewhat

repetitive but I will quote a couple of examples. "*Anthocercis* . . . cuttings strike freely in sand under a bell glass with mild bottom heat. So soon as they have well rooted, pot off into very small pots in two-thirds good loam and one of peat."

"*Banksia* . . . cuttings are generally supposed to be difficult to root but this is not the case if properly managed. Let them be well-ripened before they are taken off; then cut them at a join and place them in pots of sand, without shortening any of the leaves, except on the part that is planted in the sand where they should be taken off quite close. The less depth they are planted in the pots the better so long as they stand firm when the sand is well closed around them. Place them under hand glasses in the propagation house but do not plunge them in heat. Take the glasses off frequently to give them air and dry them or they will probably damp off. When rooted, transfer to small pots."

The main difference between the propagation instructions given for one genus and that given for another is in the state of maturity of the wood for cuttings, for example:- well-ripened, half-ripened or young shoots. You will also notice that bottom heat is recommended for some and warned against for others, and those of you who have experimented with bottom heat on cuttings of native plants will have verified these varying responses.

The Dictionary of Gardening 1885-89 marks some 270 odd species of the New Holland plants from its extensive listing of over 1200 species, as being "plants that are especially good or distinct". I wonder how many of these are being grown today.

Our *Doryanthes* were both highly regarded and described as "a genus of extremely beautiful amaryllids".

The Cape York and Torres Straits Ginger Lily or Rain Lily, *Curcuma australasica*, was also regarded as "especially good" also our black Arum, *Typhonium brownii*, as well as our two *Bowenia*, *B. spectabiles* and *B. serrulata*.

During the last century when the emphasis was on displays of showy flowering plants in pots, the Australian plants such as *Correa*, *Eriostemon*, *Boronia*, *Epacris* and *Pimelea* were among the most popular and useful.

I am astounded by the list of hybrids and selections of *Correa*, *Epacris* and *Swainsona galegifolia* that were grown so long ago.

The Dictionary of Gardening says of *Epacris*: "These are amongst the most useful of winter flowering plants either as decorative subjects or for cut flowers. They are as a rule more easily propagated and grown than Heaths and the flowers last longer in a cut state. . . The species of *Epacaris* have produced

a large quantity of beautiful garden forms that are in most cases superior to the types from which they have originated."

Following are a few of the names from an 1880 list of 31 garden cultivars: "Ardentissima, Eclipse, Fireball, Ignea, Lucifer, Sunset, The Bride, Vesta and Vesuvius". I wonder where these plants are now.

The type of gardening with which our plants became involved in the greenhouses and hot houses of England was quite different from the way we garden and plants were carefully trained to fulfill particular purposes. Some were very successful for training into columns or pillars and the best of these included *Abutilon*, several of the *Acacias*, our *Hardenbergias* and *Kennedyas* and many of our pea-flowered shrubs, over twenty genera of which contained highly recommended species.

The following quote about *Chorizema* will illustrate the high esteem in which these plants were held before 1888. "They are mostly trained on globe or other trellises with excellent effect, the whole trellis being lighted up with the brilliant beauty of their flowers slightly toned down by the pleasing forms and refreshing variations of the leaves. They are admirably adapted for clothing dwarf columns or pillars and covering dwarf walls. They also form fine loose bushes if allowed to grow freely and produce a number of shoots, the outer ones hanging over and partly hiding the pots. . . They seldom however look better than when placed in 8 or 10 inch pots clothing a globular trellis."

Highly regarded Australian climbing plants included *Hardenbergia*, *Kennedya*, *Tecoma australia* and *T. jasminoides* (now of course both *Pandorea*), *Millettia* and one of the *Passiflora*.

In recent years we are seeing attempts by nurserymen to popularize the idea of potted flowers in place of bunched cut flowers. A few of our plants were highly valued in a similar way in the 19th century because of their ability to flower prolifically while still small cutting-grown pot specimens. These plants included *Backhousia myrtifolia*, *Busaria spinosa* ("a very pretty object when covered all over with its elegant white blossoms") and a small number of our *Acacias*.

Our *Blandfordias* were praised and recommended in the highest terms: "A very beautiful genus of greenhouse bulbous plants". I couldn't agree more but how many people are growing them.

Mrs. Loudon calls *Calostemma luteum* and *C. purpurem* "very pretty plants".

The Dictionary of Gardening also highly recommends both our species of *Eurycles* as handsome bulbous plants. The ac-

cepted common name of *Eurycles cunninghamii* as long ago as 1885 was incidentally, "Brisbane Lily".

In the 1890's Guilfoyle published *"Australian Plants Suitable for Gardens, Parks, Timber Reserves, Etc."* He lists 3268 species and varieties and suggests suitable cultural uses. The book apparently had little effect in furthering the use of our plants at that time.

During the early 1900's the interest in culture of Australian plants dwindled, much like a tap running out of water. Even the Century Supplement to, The Dictionary of Gardening, notes that many genera and species are "probably not now in cultivation".

L.H. Bailey in *"The Standard Cyclopedia of Horticulture"* in 1913 makes mention of some Australian species as "popular in the early part of the 19th century — largely replaced by quick growing soft-wooded plants". This refers to the development of plants such as dahlia and chrysanthemum. Perhaps the decline in popularity was also partly at the whim of fashion.

Whatever the cause of the decline, it's worth reflecting that all this high developed culture of Australian plants was achieved without the sophisticated equipment such as misting units, automatic humidity and light control, growth promoting and regulating chemicals, technical knowledge of potting mixes, fertilizers, pest and disease control and sterilants, etc., that are taken for granted today.

QUESTIONS AND ANSWERS

SHEILA THOMPSON: The trade is criticized for not growing more of these plants but do you have any suggestions for obtaining seeds. Even if the Society For Growing Australian Plants has seed it is not readily available to the trade.

DAVE HOCKING: There is a lack of liaison between S.G.A.P. and the trade and if this continues the current interest in growing our native flora will be just another passing fashion. S.G.A.P. is seeking government assistance to collect seed and to make it available to the trade. I have investigated the possibility of a business to collect and sell seed but consider it to be non-viable at the present time.

BEN SWANE: There are restrictions against the growing of many native species — those that are totally protected. Acres of these plants are bulldozed and buried but we are not allowed to grow them.

DAVE HOCKING: Some existing legislation and misguided conservation attitudes are quite detrimental. Many species will be maintained only by getting them into the trade.

MARGARET McKAY: Flora legislation is currently being rewritten so now is the time to put forward ideas on this matter. This Society should take up the issue.

ELECTRIC SOIL AND HOT-HOUSE HEATING

PAUL de LANCE

Southern Electric Authority of Queensland
Cleveland, Queensland

The electric heating of seed and cutting beds and of hothouses has resulted in a marked improvement in plant production and quality.

With tomato seeds the heating of seed beds has reduced the time between seeding and planting by five weeks. Capsicums, which are normally difficult to raise during the winter, sold four to five weeks before seedlings planted from unheated beds. Croton, hibiscus, camellia, macadamia, celery, and passion fruit have been produced with great success, being struck and grown during the winter and sold in early summer. The grower can now compete on a market where it was not possible to do so before.

The use of a 32-volt system enables low cost, easily replaceable galvanized iron wire elements to be used. These can be installed by the grower and adapted to suit his particular conditions and application.

BED CONSTRUCTION

The following descriptions apply to seed beds and hothouse installations known to be successful. However changes in detail could readily be incorporated to suit existing installations and to cater for special plant requirements.

Exterior Seed Beds: Prepare a 6 inch deep bed of the area required above a layer of plastic sheeting, perforated to permit good drainage. The bottom two inches should be of screenings or sandy loam on which the element is run. The top four inches should be of soil or sand depending on the plants to be grown. (Fig. 1)

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The electric heating of seed and cutting beds and of hothouses has resulted in a marked improvement in plant production and quality.

With tomato seeds the heating of seed beds has reduced the time between seeding and planting by five weeks. Capsicums, which are normally difficult to raise during the winter, sold four to five weeks before seedlings planted from unheated beds. Croton, hibiscus, camellia, macadamia, celery, and passion fruit have been produced with great success, being struck and grown during the winter and sold in early summer. The grower can now compete on a market where it was not possible to do so before.

The use of a 32-volt system enables low cost, easily replaceable galvanized iron wire elements to be used. These can be installed by the grower and adapted to suit his particular conditions and application.

BED CONSTRUCTION

The following descriptions apply to seed beds and hothouse installations known to be successful. However changes in detail could readily be incorporated to suit existing installations and to cater for special plant requirements.

Exterior Seed Beds: Prepare a 6 inch deep bed of the area required above a layer of plastic sheeting, perforated to permit good drainage. The bottom two inches should be of screenings or sandy loam on which the element is run. The top four inches should be of soil or sand depending on the plants to be grown. (Fig. 1)

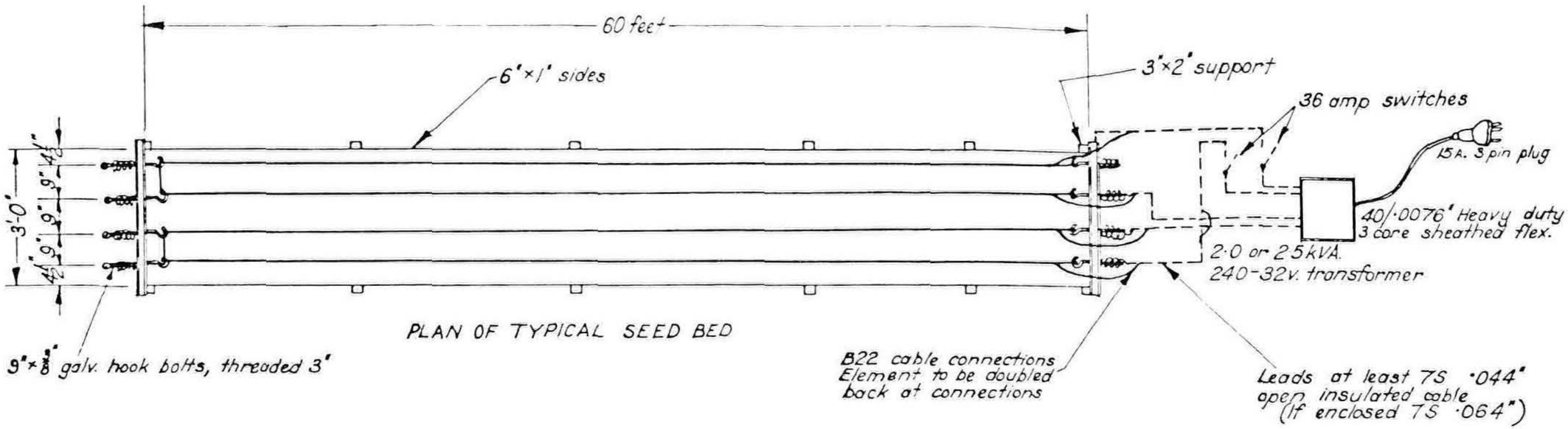

Figure 1. Construction details for a 180 square feet farm seed bed or nursery propagation bed with 32 volt electric heating system.

Hot-House Beds: Elements can be installed in elevated beds made of corrugated asbestos cement covered with flat 3/16" fibre cement as flooring and sides. A bed thickness of approximately 6 inches is common. Where adequate misting is employed the thickness may be reduced to two inches. Construction is as for seed beds (Fig. 1).

For potted plants such as African violets the element can be run in open air beneath the floor of the bench.

ELEMENT AND ELECTRICAL DETAILS

Element: The element found most suitable is 10 gauge galvanized tie or fencing wire, as soft as possible, with the length selected to suit the required heating. An estimate of the watts for various lengths of element can be obtained from Fig. 2. The length of element is the total length connected across the 32 volt supply. The wire should be as close to pure iron as is possible with a minimum amount of carbon to reduce corrosion. The connections shown in Fig. 1 consist of two elements connected in parallel, each 120 feet long and from Fig. 2 the power consumption for 10 gauge wire is 960 watts for each element.

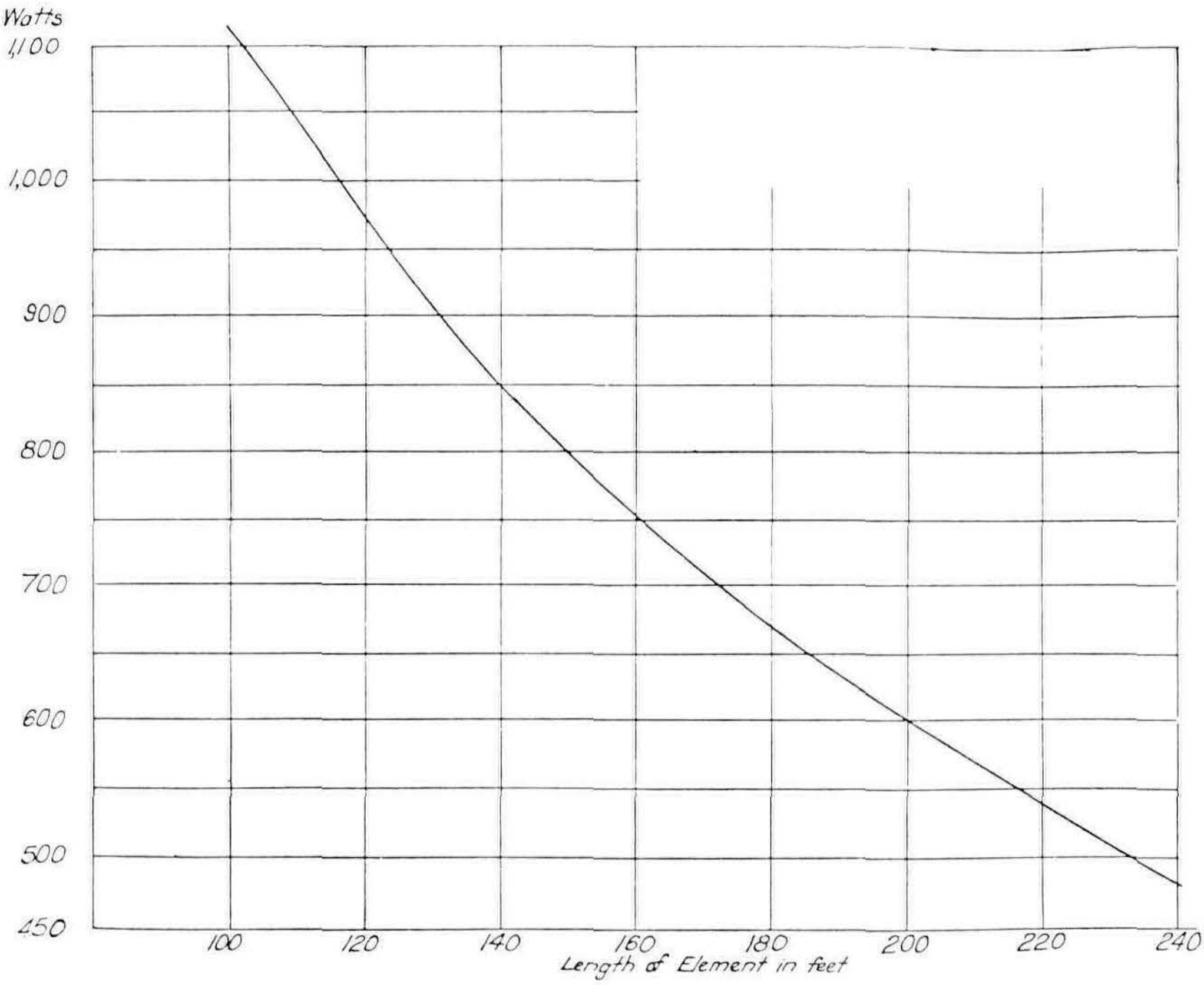

Figure 2. Average wattage for different lengths of element connected across a 32 volt supply. Element of 10S.W.G. fencing wire (soft).

Hence the total wattage is 2 × 960 = 1,920 watts. The total bed area of 60 feet × 3 feet is 180 square feet, so the system provides 10.5 watts per square foot of bed area. The wattage required per square foot can vary over a wide range up to 15 depending on the type of plant, the weather conditions, the bed location and the stage of the plants. If the two elements are connected in series across the 32 volt supply, resulting in a single 240 foot element, the total wattage — from Fig. 2 — is 480 watts, or 2.66 watts per square foot of bed area. This reconnection permits a more gradual reduction in temperature before planting out.

Corrosion is a problem where the temperature exceeds 80°F and when plant nutrients are used. Care must be taken that all connections are made outside the bed where it is cooler and where corrosion due to electrolysis at the junction of copper cable and the ferrous element can be minimized. The expansion and contraction of the element must be taken up by springs as shown in Fig. 1.

Transformer: A 240/32 volt transformer with a kVA rating at least 25% greater than the required total element wattage should be used. This results in a 2.5 kVA unit being required for the 1920 watt bed detailed in Fig. 1.

BED OPERATION

The optimum temperature and mode of operation can only be determined by experience, and only a general guide can be given.

With 10 watts per square foot a bed temperature of 75° to 80°F can be maintained. In a glass house with plastic sheeting ceiling lining this will keep the house air temperature 10° above outside ambient. When automatic misting is installed up to 15 watts per square foot may be required to maintain these temperatures. Thermostatic or manual temperature control may be used.

RESULTS

Plants produced in heated beds are stronger and more productive than those raised without heating. The time required is considerably reduced. The number of tomato fruits produced on the first trusses of the plants is much greater when raised in heated beds, due to the more favorable conditions for the young seedlings. Nurserymen are able to grow plants in winter for sale in early spring.

However, a word of caution. Before proceeding with installation it would be wise to check with your local electrical

authority to make sure that this system of heating is acceptable to them. It is a tried and proven method and certainly works well. It is widely used in Queensland and northern new South Wales.

VEGETATIVE PROPAGATION OF *EUCALYPTUS FICIFOLIA* F. MUELL BY NODAL CULTURE *IN VITRO*

R.A. de FOSSARD and R.A. BOURNE

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Abstract. The red-flowering gum, *Eucalyptus ficifolia*, is a very attractive ornamental tree which is propagated by seed because, like many tree species, it is difficult to propagate by cuttings, budding and other classical methods of vegetative propagation. Although the flower colour on individual trees is the same, it is highly variable on different trees reared from seed and can be white, pink, orange, scarlet red or maroon. A method for the clonal propagation of *E. ficifolia* using nodal culture has been developed which involves first the culture of nodes, second the subculture of nodes excised from shoots on the primary cultures and finally the initiation of roots on subcultured nodes.

REVIEW OF LITERATURE

There have been several attempts to regenerate plants from callus of various species of *Eucalyptus* (4,7,9) and successful regeneration has been reported for *E. citriodora* (1) and *E. alba* (8). Organ culture of nodes has also been successful with *E. grandis* (2,3,7). The research with *E. ficifolia* was done using the Broad Spectrum approach which was tested first with tobacco (6) and later with strawberry, and led to the development of a very high multiplication rate (10).

MATERIALS AND METHODS

Culture of aseptic seedlings of *E. ficifolia:* Seeds were treated with 0.1% (v/v) 7X detergent and 5% (w/v) calcium hypochlorite for 20 min, followed by several rinses in sterile water and were then planted on sterile medium-B (5).

Culture of nodes from aseptic seedlings: When the aseptic seedlings had developed six nodes (node 1 — cotyledonary

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node), each node was excised and, without defoliation, was planted on one of the 81 media of the Broad Spectrum experiment (6); there were thus 486 cultures, that is six node-replicates of 81 treatments. The Broad Spectrum experiment consisted of combinations of four broad categories of constituents, namely: (1) minerals, (2) auxins, (3) cytokinins and (4) sucrose plus growth factors plus amino acids, each at three concentrations, low, medium and high. This experiment with seedling nodes indicated that four of the 81 media tested might be suitable for nodal culture, and these four (Broad Spectrum codes*: LLLM, LHLH, MMHH and MHMH) were tested using nodes from adult trees.

Disinfestation of nodes from adult trees: The *E. ficifolia* trees used in this study were selected in Sydney and Melbourne, 560 and 1600 km, respectively, from the tissue culture laboratory in Armidale. Several, approximately 6 cm long, branch tips of new growth were cut from each tree and were defoliated down to about half their petioles. The cut end of each branch was sealed with adhesive paper and the branches were placed in plastic bags, closed and transported by air to Armidale (occasionally, the bagged branch tips were stored in a refrigerator at about 4°C overnight prior to air shipment). Between 24 and 48 hours after picking, the branches were treated as follows: (1) Running tap water (town supply with possibly some residual chlorine in it) for 1 hour; (2) 0.1% (v/v) 7X-detergent for 5 min; (3) individual branch tips were then treated with 5% (w/v) calcium hypochlorite (freshly prepared and filtered); (4) three rinses in sterile water; (5) 10 μM ascorbic acid for 2 hours; (6) stored in sterile water until removed for excision of the nodes.

Subculture of nodes: Primary cultures gave rise to small shoots and often multiple buds. Nodes and buds were excised and placed on fresh medium (Broad Spectrum, MHMH) for further growth; these were later subdivided and placed on fresh medium, and the process repeated to obtain clonal populations.

Induction of roots from nodes and nodal subcultures: Broad Spectrum medium MHMH was used as a basal medium to test several combinations of factors to obtain root formation on previously rootless nodal explants and subcultured nodes.

Incubation conditions: 12/12 (hours light/hours dark) at 25°C has been used throughout this research, illumination coming from GRO-LUX fluorescent lights; no other temperature or

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* The first letter (of the 4-letter code) is for the first category, minerals, the second letter for auxins and so on; L, M, H are abbreviations for low, medium and high concentrations, respectively.

light/dark regimes have been tested, nor have any combinations of an initial period of dark incubation followed by light/dark incubation, been tested, as done for *E. grandis* (3,7).

Table 1. Constituents and concentrations of medium suitable for the induction of roots from seedling nodes and nodal subcultures of *Eucalyptus ficifolia*.

Macronutrient elements (mM): NH_4NO_3(10), KNO_3(10), NaH_2PO_4(1), $CaCl_2$(2), $MgSO_4$(1.5)
Micronutrient elements (μM): H_3BO_3(50), $MnSO_4$(50), $ZnSO_4$(20), $CuSO_4$(0.1), Na_2MoO_4(0.1), $CoCl_2$(0.5), KI(2.5), $FeSO_4$(10), Na_2EDTA(10), Na_2SO_4(40).
Main carbon source (mM): sucrose (either 60 or 120)
Growth factors (μM): inositol (600), nicotinic acid (40), pyridoxine.HCl(6); thiamine.HCl(40)
Auxins (μM): IBA (indolebutyric acid)(10)
Agar (g/l): Difco Bacto-Agar(8)

RESULTS

Culture of nodes from aseptic seedlings: The experiment with seedling nodes on the 81 media of the Broad Spectrum experiment revealed many different types of responses, including five main types of callus, ten or more types of organized growth and several abnormal morphological responses. In general, combinations with the high concentration of sucrose + growth factors + amino acids favored organized normal development whereas combinations with the low and medium concentrations of this category of constituents led to unorganized (callus) growth. Particularly interesting was the formation of multiple buds on medium MMHH and MHMH; multiple bud formation is the development of axillary buds on the shoots that develop on the initial nodal cultures.

Culture of nodes from adult trees: Microbial contamination losses averaged 30% of cultures for most nodes and about 6% for stem tip cultures (these explants were obtained by removal of the leaves protecting the stem tip). Trees up to 36 years old were used in this study and some nodes from all trees sampled grew on the four media. Some nodal cultures on MMHH produced multiple buds. Many cultures were growing well on these media two months after planting and then, unexpectedly and quite rapidly, deteriorated and died. This response had also been noted with some seedling nodal cultures in the Broad Spectrum experiment. This decline and death of healthy cultures can be avoided by subculture to fresh medium, and possibly by reducing the desiccation of the medium by using

Parafilm closures, an idea presently being tested.

Subculture of nodes and buds: Nodes and buds were excised from primary cultures of seedling nodes and were tested on the same four media used for the nodes from adult trees; best growth of subcultured nodes occurred on medium MHMH. Tissue in contact with this medium became black and warty in appearance, whereas tissue not in touch developed in an apparently normal manner.

The induction of roots on seedling nodes and nodal subcultures: Medium MHMH was used as a basal medium in this work and initially three ideas were tested in an attempt to induce root formation in these rootless explants and cultures. These ideas were: (1) that liquid medium with filter paper wick support for the culture might favor root formation more than agar-solidified medium; (2) that cytokinins might inhibit root formation; and (3) that specific auxins might promote root formation. Tests were done with seedling nodes and with subcultured nodes and involved more than 500 cultures of each type. The results showed clearly that agar-based media were totally superior to liquid media both for shoot development and root formation. Cytokinin-free media were much better than cytokinin-containing media for root formation. Of the six auxins tested, IBA (indolebutyric acid) was the best. Several seedling nodes formed roots on cytokinin-free agar-based media in the presence of the high concentration either of IBA or of a few other auxins; but only one subcultured node produced roots and this was on an agar-based cytokinin-free, auxin-free medium, that is MZZH (where Z = zero). These results led to the concurrent testing of (1) various concentrations of IBA (namely: 0, 0.1, 0.3, 1, 3, 10, 30, 100 μM) on M-ZH, and (2) 36 combinations of iron, IBA, sucrose and growth factors. The second of these two experiments revealed two combinations of the factors tested capable of inducing root formation in nearly all of the seedling nodes and subcultured nodes; the two combinations differed only in concentration of sucrose, and are listed in Table 1.

DISCUSSION

This paper is a progress report on work started in November 1975, and thus covers about 10 months of intermittent research. The problems in trying to find methods for the clonal propagation of adult trees are easy to state in general terms. First, a method for ridding the microbes from the surface of the tissue to be explanted must be devised, and the disinfestation treatment should not be so severe as to harm the tissue. Second, cultural conditions suitable to promote and sustain the

healthy growth of the explanted material must be found; these include finding a suitable culture medium and conditions of incubation. Next, an optional but highly desirable stage, is to find ways to multiply and to sustain the healthy growth of the cultured material; ideally, there should be no need to initiate fresh material from the tree at intervals since this will always be attended by some contamination losses and is also likely to be influenced by seasonal conditions. Multiplication of desirable material in the culture tube offers the nurseryman year-round propagation. Fourth, the cultured material must be induced to form roots and, finally, the rooted material must be established in soil.

The first two problems were tackled simultaneously. Satisfactory disinfestation of new growth was achieved by the methods described in the section on Materials and Methods. The Broad Spectrum approach was used to find suitable media to promote and sustain the growth of nodal explants in culture and, in the first experiment, nodes from aseptic seedlings were used. This strategy permited the testing of many factors without contamination losses, but had the possible disadvantage that the media selected for seedling nodes might not be suitable for the culture of adult tree nodes in the event the four media selected were suitable for tree nodes. One of the four media was also found to be suitable for the subculture of seedling nodes thus laying the foundation for a method for multiplication in the culture tube.

By this time, it was winter and no longer possible to obtain new growth from trees. Research continued with seedling nodes and subcultured nodes to find ways of inducing these materials to form roots. Up until this stage, very few of the several thousand *E. ficifolia* cultures had produced roots, and there was little point in perfecting multiplication techniques until it could be determined whether induction of root formation was possible.

Root formation was induced in all but one of the 20 cultures on the two media described in Table 1 (the two media differ only with respect to the concentration of sucrose). These media, when supplemented with kinetin and BAP (benzyl amino purine), both at 1μM, appear to be suitable for the subculture of nodes, and are an improvement on MHMH-medium used up to this stage, since the part of the culture in touch with the medium did not become black and warty in appearance.

The research programme is continuing with emphasis on defining the factors most important to the initial culture of the seedling nodes and to their subculture, so that by the time new growth is available on selected trees both MHMH-medium and

its experimentally-determined modifications can be tested with tree nodes. It is planned to subculture these tree nodes at monthly intervals both to multiplication-medium and to root-inducing-medium to find out, first, whether these techniques will result in rooted clonal plants suitable for establishment in soil and, second, whether year-round propagation is possible with *E. ficifolia*.

Acknowledgements. The authors gratefully acknowledge the help of Mrs. Natalie Peate and Mrs. Marion Meldrum for selecting suitable adult trees of *E. ficifolia* in the Melbourne and Sydney areas, respectively, and for their help in the collection and airfreighting of samples to Armidale.

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THE USE OF SAWDUST IN POTTING MIXES

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Because the price of peat, especially the imported sphagnum type, has risen dramatically over the past few years there has been an increasing interest in the use of substitutes. One of the most widely available substitutes in New South Wales that could be used is sawdust. This has many of the desirable properties of peat. There are however several major drawbacks in the use of sawdust.

The first is that after an initial lag phase the sawdust absorbs a large amount of nitrogen from the potting mix. The rate of absorption depends on the temperature and the type of sawdust (Table 1).

Another problem is that many kinds of sawdust contain large amounts of substances (mainly phenols) which can inhibit the growth of plants (Table 1). Since most of the hardwood sawdust that is available locally is composed of two or more species it can be seen that the nitrogen uptake and the amount of toxic compounds in them will vary widely.

Although softwood sawdust is likely to be more uniform, much of it has been treated with preservatives, such as borax. Thus using them can be risky.

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Table 1. Properties of some commonly available sawdusts in New South Wales.

	Relative conc. of toxins[1]	Relative rate of nitrogen uptake[2]
Black Butt (*Eucalyptus pilularis*)	8.2	1.0
New England Black Butt (*Eucalyptus andrewsii*)	6.5	1.2
Tallow Wood (*Eucalyptus microcorys*)	6.1	1.1
Mess mate (*Eucalyptus radiata*)	4.5	1.2
Brush Box (*Tristania conferta*)	1.5	1.4
Sydney Blue Gum (*Eucalyptus saligna*)	1.3	1.4
Hemlock (*Tsuga sp.*)	1.0	1.0

[1] Estimated by light absorption at a 280 nm wavelength of an alkaline extract.
[2] Uptake of ammonium nitrate over a six week period at 20°C with a complete range of nutrients added.

Satisfying the Nitrogen Demand. This may be done in several ways.

(a) *Slow Release fertilizers.* The main difficulty in using slow release fertilizers is that the rate of release of nitrogen and the requirements of the sawdust often do not coincide. The inhibitors in the sawdust are also not removed. The use of controlled release fertilizers can be quite expensive in view of the high rates required.

Satisfactory results have been obtained, however, with growing citrus in large containers in a hardwood sawdust based potting mix. Urea-formaldehyde is added at the rate of 7 kg per cubic meter. A liquid fertilizer containing 200 ppm nitrogen is also used. Sulphur coated urea (Gold-N (R)) at the rate of 4 kg per cubic meter may be substituted for the urea-formaldehyde if the mix is not to be steam sterilized. Other fertilizers (e.g. superphosphate and dolomite) must also be used with the sawdust.

These mixes are not suitable for plants in small containers, especially not seedlings. However sawdust with added controlled release fertilizers may be used to substitute for about 50% of the peat, when growing indoor plants in medium-sized containers, i.e. about 1 litre in volume.

(b) *Liquid Fertilizer.* It is impractical to use liquid fertilizer to satisfy the entire nitrogen demand of the sawdust because of:

(i) the wide variation in uptake by the sawdust with time and

(ii) in most nurseries there will be batches of plants in potting mixes of different ages leading to an impossible management situation.

However they are an essential part of using sawdust treated by other methods.

(c) *Treating the Sawdust With Chemicals.* Several chemical processes have been developed to treat sawdust, thus making it suitable for use in potting mixes. One involves adding ammonia to the sawdust. It is then neutralized with phosphoric acid. Another involves "boiling" the sawdust in acid, then neutralizing it with lime.

However both operations require extensive capital equipment and their economics is questionable.

A simpler and less expensive system is to treat the sawdust with urea. Microorganisms in the sawdust quickly break the urea down to carbon dioxide and ammonia which then chemically combines with the sawdust. The potting mix then requires little or no N as it decomposes and toxic compounds are solubalized and readily washed out.

Treatment of sawdust. The hardwood sawdust is moistened and urea is added at the rate of 2.6 kg/cubic m. For satisfactory mixing in of the urea it first must be dissolved in water. For our purposes we have found that when mixing about 30 gallons imp. (135 litres) of sawdust in a cement mixer, dissolving the required amount of urea in 2 gallons imp. (9 litres) is satisfactory. More water may have be added however. If the sawdust is air dry (~ 14% moisture) add a total of approximately 180 litres of water per cubic metre to achieve a 100% moisture content, i.e. half the weight of the wetted sawdust should be water. For freshly milled sawdust (~ 50% moisture) add about 100 litres water per cubic metre. If water runs out of the bottom of the pile too much has been added.

This mixture is left for a minimum of 3 weeks under a plastic cover before being leached. The sawdust will turn black as the urea turns to ammonia. If there is a strong odor of ammonia from the treated sawdust too much urea has been used, and it should be left to air for a few weeks.

Mixing. A 50/50 mixture of sawdust and medium sand is used. To each cubic metre of mix the following is added:

Superphosphate	1.5 kg/cu m	
Dolomite	9.0 kg/cu m	(use less for plants that
Potassium sulphate	500 gms/cu m	require an acid media)
Copper sulphate	100 gms/cu m	
Zinc sulphate	30 gms/cu m	
Manganese	30 gms/cu m	
Ferrous sulphate	60 gms/cu m	
Boric acid	1 gm/cu m	
Ammonium molybdate	1 gm/cu m	

Liquid Fertilizer. For this mixture a liquid fertilizer should be used 2-3 times a week. It consists of:

Potassium nitrate	0.25 kg/1,000 l water
Ammonium nitrate	0.50 kg/1,000 l water

Use less for fertilizer-sensitive plants and during winter. If the pH of the mix falls too low calcium nitrate at 1.0 kg/1,000 l water may be substituted for the ammonium nitrate.

Suitability. This mix has been used to grow successfully a wide range of exotic and native plants in large containers (5 litres). It should be noted however, that it is not suitable for plants that are particularly sensitive to fertilizers.

PROPAGATION OF AUSTRALIAN NATIVE GRASSES

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The climate and soils of much of the inland region of Australia make maintenance of grassland to European standards prohibitively expensive. Maintenance conscious planners have therefore welcomed the growing public acceptance of landscapes with the yellow, red and brown tints that are characteristic of many Australian grasslands. Native grasses are now being considered for use in a variety of landscape situations. but particularly on low-wear sites such as roadside verges and medians, nature trails and dryland reserves. It is expected that the adaptation to drought and low fertility soils of native grasses will greatly improve their establishment and stability on such areas in comparison with most exotic grasses (6,7).

Basic investigation into techniques of native grass establishment was required before these could be considered as a substitute for exotic grasses. Methods have been developed for propagation from seed of four native grasses: the warm-season grasses, *Themeda australis* (Kangaroo grass), and *Bothriochloa macra* (Redleg grass), and the cool-season grasses, *Stipa begeniculata* (Tall Spear grass) and *Danthonia* spp. (short Wallaby grasses).

SEED GERMINATION AND SEEDLING ESTABLISHMENT

Seed. Freshly harvested seed of all four species is dormant due to the presence of germination inhibitors in the husks and/or the seed itself (2). This dormancy was overcome by normal storage for either 4 months for *Bothriochloa* and *Danthonia* or 6-11 months for *Themada* and *Stipa*. However, storage at higher temperatures, such as in an uncontrolled glasshouse during summer, resulted in loss of dormancy of all species after only 1-2 months.

Some modification of the seed material was necessary for mechanical sowing to allow the seed to flow freely and evenly through the sowing machine. Husks should be removed from *Danthonia* seeds whereas only the awns and hairs need be removed from *Themeda*, *Bothriochloa* and *Stipa*. Removal of the husks from these latter species results in excessive damage to the seed.

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GERMINATION

The two most important factors affecting germination are temperature and moisture (3,4).

Laboratory and field tests have shown that seeds of *Themeda* and *Bothriochloa* will not germinate until the daily maximum soil temperature is about 25°C. The greatest field germination of both species was recorded in November at Canberra.

On the other hand germination of *Stipa* and *Danthonia* seeds was less affected by temperature and, in the field, optimum seed germination of both species was recorded in March and April.

Seed germination of all four species was decreased by increasing moisture stress. *Stipa* was least affected while seed germination of *Themeda* was markedly reduced by even mild moisture stresses. This indicates a need for mulching and/or irrigation during the establishment phase.

FIELD ESTABLISHMENT FROM SEED

Small scale seed sowings have been made to determine the effects on establishment of seeding rates, fertilizer rates and herbicides (5). Preliminary results indicate that suitable seedling rates are 20-50 Kg/ha and 100 Kg/ha for *Stipa*. These rates are equivalent to 1000 germinable seeds/m^2 which is an average sowing rate of exotic grasses such as rye.

In general, the application of up to 150 Kg/ha of N:P:K (10-4-6) fertilizer had little effect on the number of established seedlings or their survival over the first summer.

Application of a paper or straw mulch at the rate of 3,200 Kg/ha increased the number of established seedlings of all species and while bitumen (12,000 l/ha) had the same effect on *Danthonia* and *Themeda* it markedly reduced the establishment of *Bothriochloa* and *Stipa*. The beneficial effect of the mulching was due to improved soil moisture retention on the mulched plots.

After six months under mulches there was little or no difference between plant survival under paper and straw mulches and no mulching. With the exception of *Stipa*, survival under the bitumen was lower than under any of the other treatments.

The application of either Diuron (4 Kg/ha or DCPA (6 Kg/ha) controlled weeds during establishment periods. DCPA was toxic to *Danthonia* and *Stipa* but had no effect on the emergence of *Themeda* and *Bothriochloa* seedlings. Diuron was toxic to seedlings of the four native grasses. However the application of activated carbon as a band or a seed pellet overcame

the toxic effects of both herbicides.

One major problem remains, however, with seed propagation. This is the difficulty in obtaining sufficient quantities of viable seed for wide-scale sowing, as all the species mentioned above produce only low quantities of seed which are difficult to harvest by commercial methods.

Vegetative propagation is practiced on a number of exotic grasses where seeding techniques are not satisfactory. Such grasses are usually stoloniferous and include couch grasses (*Cynodon dactylon*), buffalo grass (*Stenotaphrum secondatum*), Kikuyu grass (*Pennisetum clandestinum*), bent grass (*Agrostis canina* and *A. gigantea*) and marram grass (*Ammophila arenaria*). Bunch grasses, such as *Eragrostis curvula* (Love grass) where rootstocks can be easily divided into sections, are also suitable for vegetative propagation. It was felt that the same procedures could be used for native grasses, particularly *Themeda australis*, as an alternative and complementary method to seed propagation.

Themeda australis is a tufted perennial grass with an erect growth habit and with chunky seed heads on flowering stalks of approximately 1 metre high (Fig. 1). It is widely distributed throughout most of Australia from tropical regions to Tasmania. The species shows considerable variation in form and colour with season and ecotype. In the A.C.T. the leaves are usually green in spring and summer, purple-green in autumn and red-brown in winter. It is a summer grass that is frost susceptible (1). Some winter growth has been observed in mild seasons.

Figure 1. *Themeda australis*.

Themeda australis is palatable to stock in early summer but it rapidly disappears under continual grazing, especially by sheep. With fertilizer treatment it is outgrown and eliminated by exotic pasture and weed species. It is most commonly seen on non-grazed areas such as roadside verges and railway reserves, where it regenerates quite vigorously if undisturbed.

VEGETATIVE PROPAGATION

Research has been conducted to develop a practical technique for establishment of *Themeda australis* with vegetative propagules. The trials compared the survival, growth, and development of various sized propagules and compared hand planting and mechanical planting techniques.

Stock plants were obtained from local grasslands. The plants were mattocked from the site with at least 50% of the root system intact. Lifting and replanting was carried out in September and replanting was within 2 days of lifting.

For the hand-planted trial the plants were divided into the following four size classes of tussock basal area; 45 mm^2, 70 mm^2, 95 mm^2, 190 mm^2.These classes were further divided into two sub-classes of tussock height growth removed to 100 mm, and tussock left intact.

The planting area was a typical Canberra clay-loam which was rotary hoed before planting. No fertilizer was applied and the only irrigation was a watering directly after planting.

In the hand-planted trial the size classes were arranged in randomized plots, with 10 plants per plot at 0.5 metre centres. There were three replications, that is, a total of 24 plots.

For the machine-planted trial propagules were of one size only, 70 mm^2 with tussock height clipped to 100 mm. Planting was at 0.5 metre centres, using an un-modified Smallford vegetable and nursery stock planter, in a single block of 1000 plants.

Weed control was achieved by manual means. The hand-planted trial required more weeding, particularly where survival was poor, than the machine planted trial. Hand planting required three weedings for the first year, compared to two weedings for machine planting.

Results of observations for two years are shown in Table 1 for the hand planted trial and in Table 2 for the machine planted trial.

Significant increases in survival and in flower stems per plant are obvious in plants with tussock cut back at planting. However, this same treatment appears to lead to a smaller plant after two years.

The larger propagules clearly had the highest survival rate and resulted in larger plants after two years. However the smaller-sized classes actually grew at a faster rate than the larger sizes and produced more flower stems per plant, particularly where the tussock had been cut back.

Machine planting resulted in almost identical survival, and

Table 1. Survival and growth responses of a range of sizes of vegetative propagules of *Themeda australis* planted by hand in September 1974.

Sizes Square (mm)	Treatment	Sept. 1975 Percent Survival	Sept. 1976 Percent Survival	Jan. 1975 Sept. 1976 Plant Size Square (mm)	Percent Plants Producing Flower Stalks	Jan. 1975 Mean Flower Stalks Per Plant	Percent Plants Producing Flower Stalks	Jan. 1976 Mean Flower Stalks Per Plant
47	Tops intact	25.0	27.6*	194	2.5	2.0	83.3	16.1
47	Tops removed	50.0	52.5	188	40.0	2.4	80.9	32.2
70	Tops intact	52.5	50.0	186	14.3	2.2	85.0	14.8
70	Tops removed	57.5	60.0	193	43.5	4.1	100	31.4
94	Tops intact	32.5	37.5	240	2.5	3.0	92.9	10.3
94	Tops removed	72.5	72.5	191	75.9	5.4	100	27.5
188	Tops intact	55.0	62.5	260	54.5	6.6	66.6	7.7
188	Tops removed	77.5	82.5	210	45.2	5.7	83.3	21.7

* Plants that appeared to be dead rejuvenated the following year.

Table 2. Survival and growth responses of machine-planted vegetative propagules of *Themeda australis*. Propagules were 70 mm² and were planted September 1974.

September 1975 Percent Survival	September 1976 Percent Survival	January 1975 Percent of plants producing flower stalks	January 1975 Mean flower stalk per plant	January 1976 Percent of plants producing flower stalks	January 1976 Mean flower stalk per plant	September 1976 Mean plant size square (mm)
61.0	61.8*	64.2	3.5	91.6	23.3	163.4

* Plants that appeared to be dead rejuvenated the following year.

similar growth and development as the equivalent hand planted propagules.

These results, although preliminary, do indicate that *Themeda australis* can be successfully propagated by vegetative means. In particular it would seem that the slight advantage in survival by using larger propagules would be outweighed by the ease of planting and the increased material available by using smaller propagules. Also the greater vigor and greater seed production from the smaller propagules after two years suggests that these are more likely to eventually produce better establishment.

Clearly, cutting back the tussock is a beneficial treatment with all size classes and machine planting seems to be a feasible method of establishment on a larger area.

While vegetative propagation appears satisfactory for small

to medium size areas, or areas where immediate cover is essential, it seems unlikely that the technique could compare favorably with seed as a means of establishment on a wide scale.

Further research is required before this technique of vegetative propagation could be widely recommended. Seedling regeneration has commenced within the planted pots and this should be observed as a potential means of enrichment of an area with *Themeda australis*. Chemical weed control is being investigated as a management tool, as well as routine mowing. As use of Themeda increases no doubt other areas of investigation will become apparent.

CONCLUSIONS

It may be concluded that both the vegetative propagation of tussock grass as *Themeda australis* and the sowing of seed of a range of native grasses have potential for wide-scale application in landscaping. Some problems remain of which the non-availability of native grass seed on the commercial market is one of the more important. So too is the long term management of native grasslands when they are established for amenity purposes, especially in relation to mowing regimes. Some research is in progress on this aspect.

The ready acceptance of indigenous trees and shrubs by Australian landscapers should be extended to native grasses once these problems are overcome.

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PROPAGATION OF *CHAMAELAUCIUM UNCINATUM* SCHAUER BY CUTTINGS

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This hardy evergreen shrub is widely used in private and public gardens throughout many areas of Western Australia but mainly in coastal regions south of Carnarvon and inland to the wheatbelt where it is cultivated as a garden shrub in low rainfall districts and with minimum irrigation.

Known locally as Geraldton Wax, it flowers profusely from June to October. Flowers consistently of a disc of five petals are borne on the terminal growth, and have a waxy appearance. They have lasting qualities and make excellent cutting material for florists.

Leaves are short fleshy needles, soft to touch with a strong distinctive aroma when bruised and are rich in oil.

Although it grows readily from seed, about 12 selected cultivars are perpetuated from cutting-grown stock to obtain these better coloured forms. These range from white, pale pink, deep pink to purplish red.

Cuttings are taken between January to April but my best results have been from those taken in late March and early April.

Tip cuttings 2 to 3 inches long, from half-ripened wood at the base with a heel are the best. A heel is not essential but is desirable as a better callus and root growth develops.

Bottom heat is not used unless cuttings are made later than mid-May as normal autumn temperatures are sufficient.

I do not use mist in the normal sense but new cuttings are sprayed lightly once or twice each day for the first 3-4 weeks, but no later than mid-afternoon so that foliage dries off before nightfall.

A steam sterilized medium consisting of sharp sand with 25% rubbed peat moss is put into 5½" squat plastic pots which will accommodate 30 to 40 cuttings.

IBA in talc is dusted on the base of each cutting before "sticking". Currently I am using Pyco Rooting Hormone No. 4 with good results.

Cleanliness is all important. Regular removal of dying and fallen leaves is necessary to reduce fungal disease and, as a precaution, I water all cuttings with a Captan solution once a week.

I have also found that a weekly application of a hormone growth stimulant such as Formula 20 is beneficial. To save time and effort I combine this with the Captan application.

A sound root system is apparent 6-8 weeks after sticking, the pots of cuttings are then placed under a shade cloth frame for one month to harden.

Pricking off is done into 2" tubes in a light sand containing about 10% peat moss. These are placed under glass for 2 weeks, then put outside with a light shade cover over them which is removed 10 to 14 days later depending on weather conditions at the time.

Plants are potted on in the spring and placed in full sunshine. A sandy medium with a little compost gives good results and a mild fertilizer, such as blood and bone, will stimulate growth.

A SUCCESSFUL TECHNIQUE FOR GRAFTING HIBISCUS

ALEX SCOTT

Birkdale Nursery
Cleveland Road, Birkdale, Queensland

Hibiscus is a line that we grow well and have built up an Australia-wide trade supplying something like 50,000 a year in containers from a 2" tube to a 4" liner. There is a particularly strong demand for the Hawaiian type of hibiscus. This type produces extremely large flowers in some very unusual shades and colours. Examples which I feel would be known in any areas where hibiscus is grown are 'Surf Rider' and 'Golden Belle'.

When we first started to produce the Hawaiian cultivars from cuttings our stock bushes were young and vigorous and our production results were very high indeed. However as the stock bushes matured, the strike became less and less. I was faced with the decision of having to bed out new stock bushes every few years, or to look into the possibility of grafting.

We had to develop a technique that we could use as our standard procedure and one which could produce a high percentage of success. We set down a series of trials to determine:

(1) The most suitable rootstocks. The three most satisfactory cultivars were found to be White La France, Ruth Wilcox and Apple Blossom. I personally feel that Apple Blossom is the best of the three rootstocks used. They all produce long canes with well spaced internodes.

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(1) The most suitable rootstocks. The three most satisfactory cultivars were found to be White La France, Ruth Wilcox and Apple Blossom. I personally feel that Apple Blossom is the best of the three rootstocks used. They all produce long canes with well spaced internodes.

(2) The most suitable grafting method. Cleft graft was chosen.

(3) Post-grafting environment. Our first trial was to cover the grafts with plastic bags enclosing pot and all. The grafts were packed in trays of 40 and placed in a well-shaded bush house. We tried clear bags and blue bags. The results in the blue bag were far better than those in the clear bag but losses were still too great. In the next trial we put the completed grafts under mist and over bottom heat. The results here were much more promising. In most cases, a complete union had taken place in 3 weeks; they were then left in the house for an extra week before shifting into a shady bush house for hardening off. Within 7 days the plants were standing quite rigid and at the end of the second week they were ready for potting on or for sale.

As a result of this testing the following routine procedure was developed. The rootstock wood selected is usually around pencil thickness and about 5″ long. The two upper-most buds are left to produce new growth and all other buds are removed. We strike the cuttings in 9″ plastic containers in pure sand — about 30 cuttings to a container. The three rootstocks selected are noted for their quick strike and I feel that the co-factors that facilitate easy striking also assist in quicker callus and union in grafting.

When struck, the cuttings are potted on into a 3″ diameter 4″ deep growing tube and placed in the open sun for rapid root development and top growth. Once adequate root growth has taken place, the stocks are ready for grafting. We use the cleft graft which is made about 4″ from the top of the soil level in the pot. The scion that we use is of firm new growth with about 4 leaves. The diameter of the scion relates to the diameter of the stock, so that cambial contact is assured. We then paint the completed graft with a solution of Benlate and derris dust. The graft is then bound with 1/2″ clear budding tape and the upper part of the tie covered with grafting mastic. The grafts are held for 4 weeks, with bottom heat and mist, in a sarlon covered propagation house covered with U.V. inhibited polythene. The grafts are hardened off for two weeks in a 50% sarlon shade house. The grafting tape is left on at this stage to give strength to the graft, but the tapes are cut after potting on.

The plants are ready for sale or potting on 6 weeks after grafting. If scion and rootstock diameters are the same, it is difficult to even notice that the plants are grafted once the tape is removed.

Using this technique we are able to graft virtually all year,

but most grafts are made between October and March. I feel sure that the economics of grafting far outweigh a continual re-planting program of stock bushes for cuttings. Grafted plants commands a much better price than plants on their own roots. Grafted plants are more vigorous, flower better and live longer.

VIC LEVY: We have found 'Apple Blossom' hibiscus to be most susceptible to phytophthora.

ALEX SCOTT: That surprises me and is not our experience. I will check into that.

COMMERCIAL PROPAGATION OF MACADAMIAS

LINCOLN M. DOGGRELL

CSR Limited
Macadamia Orchards
P.O. Box 521
Bundaberg, Queensland 4670

Macadamia trees were regarded as impossible to graft up to the 1920's. Around this time a high school student in Hawaii successfully grafted two macadamias. However, it was probably not until the late 1940's that any large scale commercial grafting of macadamias took place in Hawaii.

In Queensland grafting of macadamias was still generally an unsolved mystery by 1960 with one or two notable exceptions. One man in particular, Mr. Norman Greber of Beerwah, had mastered the art and attempted to teach others his relatively simple, very successful grafting technique. Mr. Greber could not understand the failures of others to copy his method. This continued failure at propagation was the major stumbling block to the establishment of a macadamia industry around this time.

Mr. Greber's graft is a modified side wedge which allows almost any sized scion and stock to be united. Success rates were generally high with rootstock sizes ranging from small seedlings to limbs on topworked trees 6 to 10 inches in diameter. This method was adopted by one or two nurserymen and also by CSR for commercial propagation for several years. This graft relies on a small wood plane to achieve a flat surface on the scion. Propagator skill is required to produce a matching cut on the rootstock with a knife. Propagation rate is a maximum of 130 per day with a success rate from 60% to 90% depending on scion cultivar. This technique also requires an in-

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tensive maintenance programme for one or two years to establish an upright tree. Other methods of propagation were sought to reduce costs and to make greater use of limited supplies of scionwood.

A series of trials to test all manner of propagation techniques commenced in the mid 1960's. Among those attempted were:- Splice grafts, wedge and inverted wedge grafts, seed grafts, patch budding, chip budding, and cuttings.

Cuttings gave us limited success and a very slow growing plant. The N.S.W. Department of Agriculture had developed the seed graft. This is a method of inserting a small leafy scion into the cotyledons of a germinated seed. Initially in commercial practice this gave very variable results but this was offset by the rapidity of grafting. However, the small plants do not grow as rapidly as grafted seedlings although growth is faster than from cuttings.

Limited success was achieved with all the propagation methods tested. However, some were very demanding on a particular type of scion wood or were slow while others were dangerous for the operator. Patch budding was slow, dangerous, and takes were not high but this method appeared to have "something" other methods lacked. The advantages were that available scionwood could be used to propagate 3 or 4 times as many seedlings as for Greber grafting. Patch budding led to the idea of "punch budding" which Mr. Stan Henry went on to develop into a commercial technique.

Approach grafting is still used by one Queensland nurseryman but this is very laborious for large numbers of trees. Mr. Edward Tonks in Rhodesia has developed a leafy scion technique for small rootstocks. The grafting rate is 30 per day for a skilled operator. Obviously this method is not suited to a high wages country.

The mystery in macadamia grafting was partially removed by cincturing of limbs several weeks prior to grafting. Success rate still fluctuated. Earlier use of a simple colour test for starch accumulation in cinctured wood could have saved much time and effort. The test consists of dipping a cut end of a scion stick into a super saturated solution of potassium iodide and observing the degree of darkening on the end of the stick. The deeper the purple colour the greater the starch accumulation and the better the chance of success.

Throughout the series of propagation tests rootstock and scion vigor appeared to be correlated with success. Shade appeared to either be detrimental, or at best no improvement over full sunlight for all non-leafy scion grafting. It is now fully established that consistent high success rates may be achieved if

the rootstock and scion material are in excellent growing condition. This also enables the tree to continue to grow rapidly when planted into the field.

Vigor is probably the key which caused many failures in Australian macadamia propagation. CSR required medium sized seedlings to graft and efforts were made to grow trees 2 to 4 feet high in 8 to 12 months to reduce nursery costs. This growth rate has been achieved and bettered with trees grown in full sunlight and such healthy trees have improved the propagation success rate for grafts or buds. Such seedlings produce grafted trees 4 to 6 feet high which is suitable for orchard planting but is difficult for nurserymen to pack for consignment to customers. Thus other commercial nurserymen attempt to grow small but healthy trees but this is difficult to achieve with a tree which grows very rapidly when conditions are good. This conflict of nursery requirements with tree growth habits is responsible for the widely varied methods in the commercial propagation of macadamia.

PUNCH BUDDING OF MACADAMIA

STANLEY T. HENRY

CSR Limited Macadamia Nursery
Glasshouse Mts., Queensland

Australia has many beautiful and useful native plants but macadamia is the only one under cultivation to produce food for man.

Grafting of macadamis is not as easy, as fast, or as sure as most orchard species. This is demonstrated by the early difficulties experienced with grafting macadamia and the numerous propagation methods which have been developed.

In 1969 scionwood supplies of desired cultivars was in short supply. We offset our scionwood shortage by going onto patch budding instead of grafting. Results and propagation rate were similar to grafting. (Propagation rate was approx. 100 / man / day.) It was while doing this laborious patch budding that the idea of punch budding occurred to me.

On 15th January, 1970 two 0.303 bullet shells were used to prove that macadamia buds could be punched. Our first punch-budded trees resulted from this and tens of thousands of trees produced since then have proved the benefits of punch-budded trees for CSR Limited requirements.

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REQUIREMENTS

2 punches — each approx. 10 cm long made from tube steel of approx. 10 mm and 7 mm inside diameter. The cutting end is slightly flattened to produce a flat sided oval shape. The cutting end is then shaped to fit stems and sharpened. Two sizes allow selection in accordance with stem size.

Secateurs — Must be sharp and in good condition to allow clean removal of leaves from budwood.

Budwood — Must be in good condition where the bud will lift freely and clean. Very young wood should be avoided. Mature wood which has not lost its leaves has given best results.

PVC Tape — For wrapping the buds (a recent small trial with "Speed Easy" budding tape suggests that these may replace PVC tape).

Colgraft — For painting bud when wrapping is removed.

Rootstocks — Must be in good condition and have a minimum stem diameter of approx. 7 mm at a point approx. 25 cm from soil.

METHOD

Select internode position approx. 25 cm from soil.
Select a bud to suit.
Remove bark patch from rootstock.
Remove bud from bud stick.
Place bud in position.
Wrap bud completely with PVC tape.
Allow six weeks, then remove tape.
If bud is green and healthy cap rootstock at node above bud.
Paint bud and cut on rootstock with Colgraft.
Remove any growth from rootstock as it shows.
When bud is established remove stub from rootstock.

BENEFITS

Simple; easy; at least a threefold increase in budding rate; and, most important, a punch-budded macadamia seedling can maintain juvenile, and comparatively fast growth during the production of an advanced macadamia nursery tree.

In answer to those who suggest that we should grow cuttings or nut grafts, I can say that cuttings and nut grafts are in-

teresting alternatives which have been frustratingly slow growers in our nursery to date.

Perhaps the slow growth rate from cuttings and nut grafts is due to physiologically aged plant material. The plants produced from cuttings and nut grafts look excellent but their slow growth rate make them uneconomical as advanced nursery trees.

I believe punch budding to have application on other plants especially those which tend to have brittle, non-pliable bark.

EFFECT OF SUPPLEMENTARY LIGHT AND AUXIN APPLICATIONS ON ROOTING LEAFY CUTTINGS OF CERTAIN AUSTRALIAN SPECIES

R.K. ELLYARD

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Canberra, A.C.T.

Abstract. In studies undertaken with five Australian native species supplementary light was found to produce a small but statistically significant increase in the percentage of cuttings which rooted and in the number of roots per cutting. In a study using 9 species a concentrated-dip auxin application of IBA + NAA was found to be far superior to a talc dust containing only IBA in increasing both the percentage of cuttings which rooted and the roots produced per cutting.

EFFECT OF SUPPLEMENTARY LIGHT

In all types of plant growth light is of major importance since it is the source of energy in photosynthesis. In rooting leafy cuttings, the products of photosynthesis are important for root initiation and growth. Therefore, during rooting, light intensity and duration must be sufficient to ensure that carbohydrate production is in excess to that required for respiration.

There is some evidence that the photoperiod under which stock plants are grown may exert an influence on the rooting of cuttings taken from them. This may be related to carboyhydrate accumulation since the best rooting has been observed under photoperiods which favor carbohydrate accumulation. There are, however, examples where stock plants held under short photoperiods have produced the best rooted cuttings (9).

The photoperiod under which the cuttings are rooted may also effect root initiation. A number of workers have suggested that long days result in earlier and better rooting of many species (1,2,6,8) but delay rooting in others (4).

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Canberra Botanic Gardens
Canberra, A.C.T.

Abstract. In studies undertaken with five Australian native species supplementary light was found to produce a small but statistically significant increase in the percentage of cuttings which rooted and in the number of roots per cutting. In a study using 9 species a concentrated-dip auxin application of IBA + NAA was found to be far superior to a talc dust containing only IBA in increasing both the percentage of cuttings which rooted and the roots produced per cutting.

EFFECT OF SUPPLEMENTARY LIGHT

In all types of plant growth light is of major importance since it is the source of energy in photosynthesis. In rooting leafy cuttings, the products of photosynthesis are important for root initiation and growth. Therefore, during rooting, light intensity and duration must be sufficient to ensure that carbohydrate production is in excess to that required for respiration.

There is some evidence that the photoperiod under which stock plants are grown may exert an influence on the rooting of cuttings taken from them. This may be related to carboyhydrate accumulation since the best rooting has been observed under photoperiods which favor carbohydrate accumulation. There are, however, examples where stock plants held under short photoperiods have produced the best rooted cuttings (9).

The photoperiod under which the cuttings are rooted may also effect root initiation. A number of workers have suggested that long days result in earlier and better rooting of many species (1,2,6,8) but delay rooting in others (4).

Little is known on the effect of increased daylength on the rooting of leafy cuttings of Australian species. Work undertaken at the Canberra Botanic Gardens (5) has shown that in the case of three species studied, the extension of the daylength to 22 hours increased the percentage rooting, the number of roots per cutting, and decreased time taken for cuttings to root.

In February an experiment was set up to extend the work of McIntyre to five more species and to also study the interaction of light and rooting hormone (auxins).

MATERIALS AND METHODS

Two areas of bench, each measuring 1.5 m × 0.8 m, were set aside in the propagation glasshouse. Each area was heated by bottom heat to maintain a temperature of 25°C ± 1°C in the region of the basal ends of the cuttings. Both areas were under mist. One area received supplementary light from eight fluorescent tubes (40 watts, 1.4 m long) set 0.8 m above the bench. These lights were switched on for 22 hours per day.

Semihard material of each species was collected and 400 tip cuttings of each species prepared. Cuttings were placed to a depth of 50 mm in 100 mm square plastic pots containing a medium of equal parts of sand, perlite and peat moss. Twenty cuttings were placed in each pot. For each species 200 cuttings (10 × 20) were pretreated with Seredex 2 (3000 ppm IBA in talc). The plastic pots containing the cuttings were divided randomly into two equal groups, each containing 5 × 20 untreated cuttings (control) and 5 × 20 Seredex 2 treated cuttings. One group was placed on the control bench and the other on the bench receiving supplementary light. The pots on each bench were rerandomized three times per week.

All the cuttings of a species were harvested one week after roots were first observed out of the bottom of any pot. The cuttings were carefully removed from the pots and the medium removed from the roots by careful washing under water. The roots per cutting and the percentage rooted were recorded.

RESULTS

Data on the effects of light and auxin on the percentage of cuttings rooted is presented in Table 1. Those cuttings receiving supplementary light showed a slightly greater rooting percentage for each of the five species studied. Statistical analysis showed the difference to be significant at a 1% level.

Each treatment contained 100 cuttings. Cuttings for the five species were harvest at the following times after placement on the propagation bench. *Westringia fruiticosa*: 5 weeks; *Acacia howittii*: 8 weeks; *Eriostemon myoporoides*: 8 weeks; *Kunzea*

Table 1. Effect of supplementary light and Seredex 2 treatment on the number of rooted cuttings in 100 cutting samples from five Australian species.

		Westringia fruticosa	*Acacia howittii*	*Eriostemon myoporoides*	*Kunzea ambigua*	*Grevillea laurifolia*	*Total*	
Supplementary Light	Control	91	21	64	29	10	215	
	Hormone	89	33	58	40	13	233	
	Totals	180	54	122	69	23	448	
No Supplementary Light	Control	80	23	52	23	9	187	[1]402
	Hormone	81	27	50	30	6	194	[2]427
	Totals	161	50	102	53	15	381	

[1] Total for control cuttings.
[2] Total for auxin treated cuttings.

ambigua: 6 weeks; *Grevillea laurifolia*: 10 weeks.

Auxin treatment, however, was without effect on the rooting percentage. Statistical analysis indicated that there was no significant difference between the percentages obtained for auxin-treated and control cuttings.

A similar pattern was obtained when data on the roots per cutting was analyzed. Once again, no statistically significant effect of auxin treatment was observed. Supplementary lighting was found to produce a small, but statistically significant, increase in the roots per cutting.

EFFECT OF AUXIN APPLICATION

The ineffectiveness of Seredex 2 treatment to increase either the percentage rooting or roots per cutting was unexpected, and suggests that this method of auxin application was ineffective in getting auxin into the cutting. In recent work undertaken at the Botanic Gardens a comparison was made of the effect of method of application of auxins on rooting cuttings of several species.

MATERIALS AND METHODS

Nine species were studied. Cuttings were taken in May and struck under conditions similar to those outlined earlier in this paper. For each species, a third of the cuttings (50) were treated with Seredex 2 and a third with an IBA/NAA mixture applied as a concentrated dip. In this latter method the basal tip (5 mm) of the cutting was dipped into the concentrated dip for 5 seconds, removed and excess liquid allowed to evaporate (1 to 2 minutes) before cuttings were placed in the cutting medium. The remaining third were left untreated as a control.

Preparation of Concentrated Dip Solution. 1 gram indolyl 3 butyric acid (IBA and 1 gram naphthylacetic acid (NAA) were dissolved together in 125 ml of absolute alcohol (ethanol). This solution was diluted with 125 ml of distilled water to produce a stock solution containing 4000 ppm IBA and 4000 ppm NAA in 50% alcohol.

To produce a concentrated dip solution containing IBA/NAA at 1000 ppm/1000 ppm, 50 ml of the above stock solution was diluted with 150 ml of 50% alcohol (75 ml alcohol and 75 ml water). Dilution of 50 ml of this IBA 1000 ppm/NAA 1000 ppm with 50 ml of 50% alcohol produced an IBA 500 ppm/NAA 500 ppm concentrated dip. All solutions were stored in tightly sealed brown glass bottles below a temperature of 3-5°C. Solutions were allowed to return to room temperature before use.

RESULTS

Data for seven of the species studied is presented in Table 2. With the partial exception of *Calothamnus validus*, all cuttings at time of harvest were green and healthy in appearance. Five species, *Boronia heterophylla*, *Calothamnus validus*, *Callistemon viminalis*, *Prostanthera ovalifolia* and *Phebalium rotundifolium* showed a significantly higher percentage rooting for the concentrated dip treated cuttings than with either the talc dust (Seredex 2) treated or control cuttings. This was most marked in the case of *Prostanthera ovalifolia*. Three of these five species, *Prostanthera ovalifolia*, *Phebalium rotundifolium* and *Callistemon viminalis*, also showed a significantly higher number of roots per cutting following concentrated dip treatment.

For *Boronia heterophylla*, no difference was observed between the concentrated dip and talc dust treated cuttings as to the roots per cutting. A difference was observed, however, in the amount of callus and the position of the roots. The talc dust treatment produced a bulb of callus on the basal tip. Roots were confined to this area. The concentrated dip treatment, by contrast, produced callus extending up to 2.5 cm back from the basal tip. Root formation occurred in the extended callus region producing a better root system.

Malaleuca pulchella and *Correa pulchella* showed a high percentage rooting for all three treatments. For both species, however, there were twice as many roots per cutting in the concentrated dip treatment than in the other two treatments. In the case of *Correa pulchella* a difference was also observed in the position of the roots. For both talc treated and control cuttings roots were confined to the basal tip while the concen-

Table 2. Effect of rooting hormone on the percentage rooting (%R) and roots per cutting (R/C) of seven Australian species.[1]

	Boronia heterophylla		*Calothamnus validus*		*Callistemon viminalis*		*Correa pulchella*		*Melaleuca pulchella*		*Prostanthera ovalifolia*		*Phebalium rotundifolium*	
TREATMENT	**%R**	**R/C**	**%R**	**R/C**	**%R**	**R/C**	**%R**	**R/C**	**%R**	**R/C**	**%R**	**R/C**	**%R**	**R/C**
Control	34	1.4	0	—	14	2.0	97	8	90	2.8	32	2.9	22	1.9
Seredex 2	52	1.9	6	1.6	30	2.3	87	10	96	2.8	20	3.0	16	2.0
1000 ppm/ 1000 ppm dip[2]	70	2.1	30	1.5	52	4.9	100	19	96	5.6	100	15	64	3.0

[1] Each treatment contained 50 cuttings. All cuttings were harvested after six weeks.
[2] 1000/1000 ppm = 1000 ppm IBA: 1000 ppm NAA in 50% alcohol.

trated dip treatment produced callus and roots extending 2 cm back from the basal tip.

The results obtained with two other species, *Persoonia chamaepitys* and *Grevillea* × *gaudichaudi*, are presented in Table 3. In this study, two concentrations of IBA/NAA, applied as a concentrated dip, were compared with Seredex 2.

For *Persoonia chamaepitys*, IBA/NAA at 500 ppm/500 ppm was the most effective treatment in initiating roots. Both concentrated dip treatments resulted in the blackening and death of cuttings. This was much more prevalent in the case of the 1000 ppm/1000 ppm treatment.

The two *Grevillea* × *gaudichaudi* collections differed in their response to the concentrated dip formulations. For the first collection the 1000 ppm/1000 ppm concentrated dip produced the highest percentage rooting while the 500 ppm/500 ppm treatment was the more effective treatment in the second collection. In the latter case the 1000 ppm/1000 ppm treatment resulted in either the rooting or death of a cutting; no unrooted healthy cuttings were observed.

Table 3. Effect of method of application of rooting hormone on the percentage rooting (%) and roots per cutting (R/C) of two species.

	Persoonia chamaepitys		*Grevillea* × *gaudichaudi* Collection 1.		*Grevillea* × *gaudichaudi* Collection 2.	
TREATMENT	**%**	**R/C**	**%**	**R/C**	**%**	**R/C**
Seredex 2	0	—	13	1.3	38	1.9
500/500 ppm dip	52	—	25	1.5	76	4.1
1000/1000 ppm dip	14	—	70	2.1	22	4.0

DISCUSSION

Although considerable research has been undertaken into the effect of supplementary light on the rooting of cuttings, no clear picture has emerged. The role of light would appear complex. In this present work a beneficial effect for supplementary light has been demonstrated. The small size of this effect, however, may not justify the expense associated with installation and running cost of a light system.

A more profitable area for development might be in the area of exogenous auxin application. Talc dust formulations of auxin have generally been more widely used in the rooting of cuttings than have concentrated dip formulations, possibly because of ready commercial availability and their ease of application.

The work presented here has shown the talc dust formulation used, Seredex 2, was without effect. Its use did not increase percentage rooting or roots per cutting over the levels obtained for the controls.

The results presented in Tables 2 and 3 clearly show the superiority of concentrated dips of IBA + NAA over the talc dust application of IBA alone, a result in agreement with those of Heung *et al* (3) and Whalley (11).

The effectiveness of the concentrated dip treatment is undoubtedly related to a more efficient uptake of auxin by the cuttings. Its use, however, is not without problems; for example, the possibility of auxin burn if too high an auxin concentration is used. As Wain (10) has pointed out, the auxin concentration which is most active in rooting is often close to the toxic concentration.

Some horticulturists, in selecting the concentration of hormone to use, have applied the rule: the more tender the cutting material the weaker the hormone preparation should be. The results obtained in this work would not appear to support this view but instead support the findings of Roller (7); that a soft tender cutting can withstand hormone at a strength which would be fatal to a hardwood cutting. The two species which showed considerable hormone burn when treated with the 1000 ppm/1000 ppm concentrated dip were *Persoonia chamaepitys* and the second *Grevillea* ×*gaudichaudi* collection which had the hardest cutting material. The first *Grevillea* × *gaudichaudi* material was softer than the second. Some burn was also observed with *Calothamnus validus* which had the hardest material of the species listed in Table 2. Thus the problem of auxin burn may be reduced by using softer cutting material. Whalley (11) has also reported success in the elimination of auxin burn by the incorporation of 2,4,5 — trichlorophenoxypropionic acid

(0.1 ppm) into the concentrated dip. Experimental work is planned to investigate both these possibilities.

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POINTERS FOR SUCCESSFUL GERMINATION OF PALM SEED

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My first experiences at germinating palm seed showed that freshness of the seed was an important factor. Fresh seed of the 'Kentia', *Howeia fosteriana*, and *Phoenix canariensis* palm was available and germination never presented a problem. Seed of *Phoenix roebelini*, 'Dwarf Date', had to be imported so was up to many months old at arrival. Germination was poor and sporadic.

Subsequent tests with a variety of palm seed showed conventional techniques such as filing, chipping and acid baths for aiding germination of hard-coated seeds were ineffective.

In 1958 Dr. Walter Hodge, then President of the Palm Society, visited the Botanic Gardens and this led to exchange of seed and information from authorities such as Bruce Ledin, Stanley Kiem, Nat De Leon, Harold Moore Jr., and a host of others.

As a result of the exchange of ideas, a lot of experimentation, experience, and a regular supply of seed, the following facts clearly emerged:

1. Seed must be freshly harvested to successfully germinate.

2. Only mature seed will germinate.

3. Many palm seeds, despite their solid appearance, are viable for a short period only.

4. Correct storage from harvesting to sowing is of the utmost importance. Pack in slightly moist peat moss or vermiculite in a plastic bag.

5. Temperature of the atmosphere and the seed-raising media greatly influences germination.

These all are simple factors common to a wide range of seeds so why must palms differ?

Some knowledge of the palm seed is essential to understand just how it may quickly lose its viability. The palm seed normally has a thin outer coat. It is made to appear hard by the endosperm which is tightly held against the shell or seat coat. The embryo of the young plant is supported by the endosperm. When the seed is exposed to hot, dry temperatures, the embryo

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[1] Curator

shrinks very rapidly. The greater the shrinkage, the slower is the germination, the plants are less vigorous and also percentage germination is lower.

This is why seed of many species should not be gathered off the ground if they appear to have been there for any length of time. If there is browning of the endosperm the seed is getting old; if clear white, it is fresh.

The results of an experiment carried out with *Livistona australis* using 100 seeds freshly harvested and 100 seeds which had been on the ground beneath the tree for approximately six weeks, are shown in Table 1.

Table 1. The effect of aging on germination of 100 *Livstona australis* seed in 4-inch deep flats of equal parts peat moss, sand, and vermiculite.

	Number Germinated	Days to Germinate
Fresh seed	100	42
Seed off ground	46	52 to 60

Further evidence of the importance of using fresh seed was obtained with *Linospadix* seed kept in uncontrolled storage for six weeks. These seeds failed to germinate. In the following year fresh seed were harvested and planted the same day and all germinated within 35 days. Some benefit can be obtained from soaking seed collected off the ground (Table 2).

Table 2. The effect of soaking 100 seeds in water for 48 hours. *Livistona australis* seed collected off the ground.

	Number Germinated	Days to Germinate
Dry Seed	42	50 to 74
Soaked Seed	68	48 to 60

Temperature and atmospheric conditions can also influence germination of palm seed as shown in Table 3.

Table 3. The effects of temperature and atmospheric conditions on germination of *Livistona australis* seed.

	Flats in the open	Greenhouse: bottom heat (25°C)	Greenhouse: bottom heat (25°C) + cloche cover
Average day temp. (°C)	27	25	—
Average night temp. (°C)	21	22	—
Percent germination	92	100	100
Days to germinate	49	42	38

While temperature was not measured beneath the cloche it would have reduced the daily fluctuation and probably was close to 25°C throughout. This speeded up the germination.

I also found that 98% of freshly harvested *Phoenix roebelenii* seed placed in a plastic bag with moist sphagnum moss germinated in 33 days while the same seed in conventional peat-vermiculite-sand flats took 46 days to reach 90% germination.

Recently I saw this method being used in Fiji for the germination of *Licuala grandis* seed. I was informed that germination took place in less than 90 days, which is fast for *Licuala*.

Of course it must be realized that palms germinated in this way have to be handled very early. They are picked up by tweezers and placed into community containers or, better still, singly into tubes. Seed of *Archontophoenix* could be tipped out on to flats and covered, and handled again at a later date.

The main advantage of the plastic bag method appears to be —

(1) No watering required.

(2) Faster germination.

(3) Greater germination percentage with some species.

It appears desirable to completely remove all outside pulp prior to sowing whether it is still fleshy or dried; the major reason being to lessen the likelihood of fungal infection. The flesh of Kentia is removed by soaking in tepid water for 24 hrs. During my American tour in 1970, I found some palm growers immersed their seed in a fungicide preparation prior to sowing, maintaining that even small particles of pulp left on the seed could induce fungus development detrimental to germination.

Seed also has to be free of insect infestation. A variety of weevils attack seeds of many species prior to maturation. Locally produced seed of *Phoenix roebelenii* is often affected, therefore it has to be inspected prior to sowing.

Local experience has also shown that shallow seed-raising vessels can have an adverse effect on the germination or growth of some palms. With some species the hypocotyl moves down very quickly and when it strikes a solid bottom it is damaged. Germination ceases immediately or if top growth has commenced, the young plant quickly dies. In other cases, when in a shallow vessel, the roots of palms which grow rather rapidly can become much entwined and may be severely damaged during the transplanting operation.

Transplanting is best if done at the stage when the seed leaf has become fully developed. Under controlled growing conditions, transplanting may take place almost at any time if required; however, under most conditions, October to March normally produced the easier establishment of palms.

There is no magic in the raising of palm seed; it is merely a common sense approach to collecting, storing and dispatching — and finally sowing and transplanting. In every case, speed and thoroughness are the essentials.

THE NEED FOR PLANT BREEDER'S RIGHTS IN AUSTRALIA

A.T. KEANE
S.A. Carnations
Devon Road, McDonald Park
South Australia

Unless some form of national protection is established the achievements of plant breeders will be small and the immense possibilities of breeding from our native flora will not be realized. With other countries having their protection legislation this will be our loss unless we act quickly. Another factor is that with this protection overseas it is now almost impossible to introduce our strains to them without having reciprocal protection.

I, and other breeders, have made great efforts over recent years to get this established but nothing has been achieved. It has, however, been a great pleasure to know that all our State and Federal Nurseryman's Associations have formed a Plant Breeder's Rights Committee and are very active in this field. Currently, States have the power to enact appropriate legislation but I can not see the possibility of uniform legislation unless the states give this power to the Australian Federal Government.

An ordinary patent was taken out three years ago on a winter-flowering carnation in the hope that a basis for a High Court test case may be developed. In the absence of any favorable advice the patent has now elapsed. Perhaps different wording of the original patent would have improved the chances and if anybody is considering launching a patent of his own I will be pleased to supply a copy of our legal advice.

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MEETING THE CHALLENGE OF INCREASED DEMAND FOR GROUND COVER PLANTS

B. MINIUS

CSIRO, Division of Plant Industry
Canberra, A.C.T.

The magic of landscaping is definitely here to stay and we are faced with the challenge of producing exactly what customers want.

We have at least four major groups of ground cover plant users:

(1) Suburban home owners

(2) Suburban and city townhouse and flat owners or dwellers

(3) Urban landscape contractors

(4) Contractors of large scale landscape restoration, conservation and management projects.

The first two groups of customers deserve particular attention. They buy mostly exotic intensive-care ground cover plants. Plant propagators can foster business goodwill and can make a major contribution to the aesthetics of the environment in which these people live by merchandising well selected, high quality plants for the particular locality.

Sometimes these customers will need advice on how to use ground cover plants to the best advantage, how the ground cover plants can display other taller plants to advantage and how, with combination of ground cover and larger shrubs and trees, their homes, townhouses or flats can be landscaped without overcrowding or hiding their residences. A little effort in experimenting with these plants and propagating in sufficient quantitites, slightly younger plants in smaller containers will mutually benefit us and our customers. Also, it is within the capacity of the average plant propagator to offer customers the most suitable ground cover plants on a pre-order basis, grown specially for home landscapers in smaller tubes or pots arranged in dozens in seedling boxes etc., thus enabling those customers to buy larger quantities of ground cover plant at prices they can afford.

The third and fourth groups of our customers — the urban and industrial landscape contractors, usually pay good prices for large volume without question. But, they have to meet specifications and therefore, if we want to supply large contractors with high quality plants, methods and management have to be extremely efficient. It is, however, a very challenging new field for most plant propagators.

Every region of Australia does have its own specifically adapted assortment of native plants with potential for large-scale ground cover projects. Landscape architects and designers feel a great need for hardy, handsome and low maintenance natives. The local environment in every locality of our great country could be enhanced more economically and more sensibly managed if we would offer for such large projects enough good native ground cover plants.

The plant propagator has an important part to play in this field. We could, in our way, contribute in the search for, discovery of, selection of, and finally the breeding of new cultivars of native species of ground cover plants.

We could be the first supporters and possibly conveners of Regional and National Centres for native plant research, from which breeding and distribution of clonal material to plant propagators could occur. We badly need such centres; centres supported by adequate funds and with continuity of set programmes that could develop major discoveries and production of good material. It is our task to be the first advocates of such a concept. All those natives:- *Hibertia*, *Pratia*, *Podocarpus*, *Myoporum*, prostrate *Grevillea*, *Petersoonia*, *Notelia*, geranium, *Parahebe*, *Scaveola* and many other, known and unknown native plants and grasses suitable for the role of ground cover plants are important enough to go Regional or National for their improvement.

PRACTICAL HORTICULTURAL TRAINING

JOHN H. COLWELL

Panorama Nursery
Silvan, Victoria

I have spent many years in different branches of horticulture. Never have I seen an area that needs more attention than practical training. The trade is crying out for help in training — training for young and old; for nurserymen; and even the teaching staff themselves. Many think that the institutes are not geared to cope so they will not send their young to train there. The whole structure of training must be overhauled. There are many dedicated people working hard at it now but nowhere near enough. Training is the responsibility of all in the trade — educators, nurserymen, parks departments, botanic gardens, apprenticeship boards, students, apprentices, and nursery staff. We must all work together to get the results.

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EDUCATION

Everyone in horticulture should have a sound general standard of education, including an understanding of botany which is most important to the horticulturist of today. A greater understanding of the plant and its functions is required if we are to advance in the fields of tissue culture, controlled environment growing, etc. Knowledge of the requirements of the plants is essential if we are to come closer to our goal — "The production and growing of good healthy plants at a minimum cost".

BOTANICAL GARDENS

These are supposedly educational centers for all interested in plants but where are those natural order beds so vital to the study of plant families? Many students work hard to get a training place in these gardens for the status alone. How well are they really trained? Most of them are being used as general labor under no supervision at all.

HORTICULTURAL INSTITUTES

There are very few of these and they are overloaded. Therefore they should be used more for weekend training. More of the teaching staff should visit other establishments to get a better understanding of what is required in the field. It is no good sitting back and waiting until someone else asks for help. The trade is by-passing many of these establishments because they are too slow to respond to their needs; many go outside this country to get answers that should be there.

How many of the teaching staff of training colleges do you find at lectures held outside the normal working hours? Very few I can assure you. Many seem to think that when they became teaching staff their own training ended. Students complain of staff not being up to date with nursery practice. Horticulture is changing so fast that you can't expect every teacher to be an expert in all branches, but what is expected of them is that they go into class with up-to-date information on the subject of the day. They should spend a few hours on preparation of their lecture and not rely on last year's paper. A call to one of the experimental stations will give them up-to-date notes on particular procedures.

All teaching staff should keep up-to-date with all progress reports on experimental horticulture, both here and overseas.

PARKS DEPARTMENTS

I was surprised to find so few trained people in horticulture but what can you expect when many of their superintendents have to take orders from non-horticultural trained shire

engineers, or the local conservationist. The parks do not seem to have any power at all and lack the driving force that they should have.

I have served in parks departments overseas and there is no way those departments would tolerate electricity authorities or anyone else mutilating their trees. There is a difference, of course — street trees and nature strips are planned by parks departments, planted and maintained by them. Trees are inspected regularly by a tree specialist, not just by a truck driver who happens to pass by.

Overseas parks departments do much of the training of the young. Basic training is commonly over four years with one year spent in glasshouse production, one year in turf management, one in ornamentals and one in nursery practice. This may be supplemented by a day release programme and one evening class. The day release courses are held at horticultural colleges or stations. A lot of nursery money goes into these departments to help better the training in horticulture. Evening classes are usually run at local schools by staff of horticultural establishments. All are qualified teachers with many years of practical experience as well. At each of these classes they spend at least 20 minutes on identification, not only of plants but fertilizers, dusting powders, and materials used in the trade, diseased plant tissue, physiological disorders, etc. After four years of this sort of programme a well-trained student emerges ready to start training in specialized fields or to enter tertiary education for higher training in plant pathology, horticultural engineering, etc.

NURSERYMEN

What does he offer the young in training? Many nurserymen can not be bothered with an apprentice because they look at it in a selfish way. Why should he train them for someone else — what rubbish! They seem to forget that their manager or foreman was trained by some other nursery. Many who take apprentices have inadequate training themselves to be able to train them in a proper manner, and often have not even bothered to look at the training syllabus. There are, of course, many well-trained and very good nurserymen and I think thaf it is to these that we should look for help in practical training. Many of them are working hard for the trade now but perhaps they could take a practical class within their own establishment, say one Saturday per year. It would help to widen the range of training for the young and give them more interests and a wider range of practical experience than they could ever obtain from the institutes.

APPRENTICESHIP BOARDS

I think that they should take a good look at all aspects of the trade — find out just what is required to train a good horticulturist because there are so many different branches to study. A syllabus must be worked out for training so the apprentice could manage any position, be it parks, landscape or nursery. The apprenticeship board does not seem to know that one of the hardest jobs, and one that takes great skill, is watering. They seem to think that any old laborer could do it. As every nurseryman would tell you the man who can water properly is worth his weight in gold.

THE APPRENTICE OR STUDENT

He must ask himself if he really wants to be in horticulture, because you have to be dedicated to stay on top. Many students do not have their hearts in it. We find out when they go home without letting you know that they have not watered the last batch of plants potted, or walked past plants knocked over by the wind without picking them up. He must enjoy working with plants or it will be a waste of everybody's time. He must ask questions about his work and show interest. In so doing he will learn a lot faster and become more efficient in his trade. A scholarship to train for a year overseas should be made available to the apprentice showing most promise and dedication to the trade. This would give them more incentive to study harder and, let's face it, without hard work they are simply not going to make the grade. He must be prepared to give up more of his own time for evening study, attending as many lectures as possible on any subject relating to the trade.

We must also make reward to the craftsmen. They are the ones responsible for the output in our nurseries with their particular skill of grafting, budding, etc. They should be paid more for the years of experience that they so willingly pass on to the young person in training.

If we are to become better horticulturists we must strive to meet the need for better training than we have today. As I have said before, it is the duty of all to work together; there is no room for couldn't-care-less attitude within the trade. If we all pull together we may lessen those cries for help that are always with us at present.

DEVELOPMENT OF NURSERY FACILITIES AND TRAINING PROGRAMMES AT THE QUEENSLAND AGRICULTURAL COLLEGE

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The Queensland Agricultural College offers a range of full time course in horticulture, ranging from a two-year Associate Diploma courses designed to train technicians and supervisors in the various horticultural disciplines, to a degree course in Horticultural Technology.

Traditionally, horticultural teaching at the college has centered around fruit and vegetable production, but now the scope has expanded with the introduction of specialist subjects such as Nursery Production, Ornamental Horticulture, Landscape Gardening and Turf Management. These specialist subjects are designed to meet the needs of the various sections of the horticultural industries and they have originated partly as a result of pressure from industry groups, such as the Queensland Nurseryman's Association, and the International Plant Propagators' Society. Our main emphasis now is on the development of the necessary practical facilities to effectively teach these subjects, particularly the facilities for the teaching of nursery production.

Plant propagation and nursery production are fundamental parts of the whole field of ornamental horticulture. Students intending to enter sectors of the horticultural industry such as Nursery Stock Production, Garden Center Management, Parks and Gardens Departments and Landscape Contruction must all possess a wide knowledge of plant production techniques.

To this end a one-hectare site has been allocated and development of a nursery has started.

EDUCATIONAL USES OF THE NURSERY

TEACHING OF PLANT PROPAGATION PRACTICES:

Nursery Stock Procedures: The needs of students entering the plant nursery industry will be catered for by regular participation in the propagation, potting and general care of a wide range of plant material, in addition to regular work on nursery design and management, plant protection studies, and mechanization.

To inject realism into the programme it will be necessary to structure the nursery on sound commercial lines. It is our intention that a significant proportion of the output from the nursery

will be sold. The income generated will go some way towards offsetting running costs of the nursery. However, commercial considerations will not be allowed to take precedence over educational requirements; we must not lose sight of the primary reason for our existence. It is not our intention to set up in competition with local nursery stock producers. All produce will be offered for sale to the wholesale trade and the Queensland Nurseryman's Association has already indicated its support for this project. The college will work closely with the Association and a joint decision will be made on the range of plant material to be grown for sale.

As previously mentioned, the main emphasis will be on production for wholesale outlets but when the nursery becomes well established we must begin to think about serving the needs of the retail nursery industry and establishing a model garden center to demonstrate modern retail systems.

The courses are designed to serve the needs of students intending to enter the horticultural industries at both management and technical levels. The facilities being developed must reflect this and so will be of the types that a commercial grower would use. We wish to avoid unneccessary expenditure on elaborate constructions which do not relate directly to current commercial practice.

We believe that the acquisition of a wide range of practical skills is an essential part of the education of horticulturists and the nursery complex will provide a central location for the teaching of these skills. It is intended that the nursery will propagate a wide range of ornamental plants of lesser commercial importance to enable students to become familiar with a wider range of plants than is normally available commercially. However, we do not imagine that the college nursery will be able to provide the full range of experiences necessary to train a competent horticulturist and it will be supplemented by visits and exercises in local nurseries as well.

Parks and Gardens Personnel: Students intending to specialize in parks or other government horticultural agencies require the same detailed knowledge of plant production. Therefore, a range of similar plant production exercises will be undertaken by students specializing in this sphere. Parks and gardens do have certain specialized requirements and it is intended that an area within the nursery will be set aside to cater for these requirements; e.g. the production of advanced nursery stock for "instant" landscaping.

It is proposed to develop a six-hectare site adjacent to the nursery as an environmental park. The establishment of the park will fulfill an extremely valuable educational requirement

of allowing students of ornamental horticulture to gain experience in park design and in the utilization of plant material raised in the nursery.

Annual bedding plants will also be produced in the nursery. Students will be involved in the production of batches of flowering annuals to provide successional displays within the environmental park.

Landscape Gardeners: The basic constituent of all landscapes is plant material. Intending landscape gardeners must be capable of growing a range of plant material to a size suitable for planting out; therefore a detailed knowledge of plant propagation is an important requirement. To enable these students to gain experience in design and in plant utilization, it is intended to initiate a series of design projects within the environmental park utilizing plant material raised in the nursery.

Fruit Producers: Commercial fruit growers require a knowledge of rootstock production and budding and grafting techniques used in the raising of fruit trees. Many of the practical skills necessary are common to other disciplines and students specializing in fruit will undertake a series of propagation exercises along with other groups. An area of the nursery will be set aside to cater for the specialized requirements of fruit tree production.

Turf Producers: Turf production is a rapidly expanding sector of the horticultural industries. The demand for good quality turf for landscape projects and home gardens is expanding at such a rate that the conventional production methods will soon be inadequate to cope with the projected demands. New production techniques have been developed to shorten the growing period, and it is proposed that an area within the nursery be set aside to evaluate these techniques for Queensland conditions.

TEACHING OF HORTICULTURAL ENGINEERING:

As the nursery is developed, a range of specialized horticultural machinery and equipment will be built up. This will be an invaluable asset in familiarizing horticultural students and others with a wider range of machinery and equipment. Examples are automatic irrigation equipment, mist propagation equipment, automatic glasshouse ventilation, media sterilizing equipment, media mixing equipment, potting machines, etc.

TEACHING OF BUILDING CONSTRUCTION:

During the construction period there will be considerable student involvement in a range of building construction exercises.

TEACHING OF PLANT PROTECTION;

The appearance and value of nursery stock can be seriously

affected by a wide range of pests and diseases. Weed control can be another major factor in maintaining plant quality. The College has a specialist team of plant protection staff who will be concerned with the problems of nursery production. It will also be very much to the advantage of the local nursery industry to be able to obtain precise information on the latest plant protection techniques.

TEACHING OF BUSINESS STUDIES AND VALUATION:

The nursery will provide a more realistic practical teaching facility to widen the range of business experiences of students. Examples of possible study areas including work study, financial planning, accounting systems, labor surveys, profitability studies, project evaluation, marketing investigations, etc.

PRODUCTION OF PLANT MATERIAL FOR LABORATORY USE:

It is envisaged that the nursery will raise substantial amounts of plant material for laboratory investigation work.

SITE FOR STUDENT AND STAFF RESEARCH WORK:

In addition to direct teaching use it is expected that the nursery will be used for practical project work by students and for staff research programmes. Third and fourth year degree students must carry out detailed project work as an essential part of their course. In this respect we must also look towards the future. It is intended that Graduate Diploma and Masters degrees be established in the future and provision for space must be made.

AUSTRALIAN NATIVE STOCK REPOSITORY:

One area in which we can be of value to the nursery industry is in being able to maintain a collection of the most useful Australian native plant species not readily available through commercial channels. Large numbers of cultivars and hybrids of native species are being introduced into the trade but by no means all of these are good enough for large scale production. The environmental park is a suitable area to act as a repository for this material and we aim to evaluate the performance and to propagate the most suitable lines for supply to interested nurserymen.

VIRUS-FREE NURSERY STOCK REPOSITORY:

As developments proceed we should undertake the production of, and maintain, a range of virus-free propagation material for distribution to nurserymen. The plant protection group at the College is concerned with an integrated system for maintaining plant health and quality and would have a major role in this programme.

BENEFITS TO THE NURSERY INDUSTRY

Apart from the direct benefits to be gained from the availability of a pool of well-trained nursery staff we feel that this development can provide other substantial help to the industry. A fund of specialized knowledge will be available at the college to help overcome the problems of the industry and, we hope, lead the way forward with the introduction of new techniques. We intend to organize a series of field days at which growers can see a range of production techniques and discuss problems with other growers and with college staff. The college staff will also be available for consultation with individual growers and a two-way interchange of ideas and information will develop to our mutual advantage.

CUTTING-GRAFTS OF CAMELLIA RETICULATA

STEVE CLARK

Camellia Grove Nursery P/L
St. Ives, New South Wales

Camellia reticulata has been propagated in this nursery for many years by cleft grafting. However the numerous disadvantages — use of four-year-old understocks, no buds formed in the first season after grafting, single stem with few or no lateral branches for the first year — made a cutting-graft seem worthwhile trying.

A side veneer graft carried out in the summer has worked well. The procedure is as follows.

Camellia hiemalis 'Kanjiro' is used as the understock. A vigorously growing plant that has made stout shoots on the top is selected. Understock cuttings are prepared about 5 inches long with 2 or 3 leaves. A single sloping cut about 1/2 inch long is made into the stem about 1½ inches from the base. This is where the wood is thickest and the possibility of cutting right through is minimized.

The scion of the desired cultivar is prepared by cutting to approximately 3 inches in length with two leaves at the top and the base is shaped into a wedge about 1/2 inch long. The scion is inserted into the cut in the understock and tied at this point. If the scion and the understock are exactly the same diameter there is no problem at all, but in most cases it is necessary to line up the cambium layer on one side only and overlap or underlap the other side as required. Where the scion is grossly oversized trim down one side to approximately understock size and proceed as before. For best results tie with a rubber band

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but packing tape will do and is cheaper.

Place the newly prepared cutting into a normal cutting medium to a depth that will cover the graft union by about one inch. Treat as for a cutting until roots have emerged from the base of the understock. By this time callusing of the stock to the scion should have taken place. When the cutting-graft is removed from the growing medium roots may also have emerged from the union. Simply cut these off. The next step is to cut off the portion of the understock above the union but as close to the union as possible and from then on simply treat as a cutting and pot up.

Advantages of the cutting-graft system are:

1. There is no need to grow understock for 4 years and then cut it off.

2. There is no need to keep the plant for a further year or two before releasing it for sale.

3. The cutting-graft is at least as reliable as the traditional graft but, if it is unsuccessful, the loss is not that of a plant that has been grown for 5 years.

4. Preparing the cutting-graft is more time consuming than making ordinary cuttings but not as time consuming as the traditional graft.

5. The cutting-graft plant can be released for sale after 3 years compared with at least 5 for the traditional graft.

6. Whereas the traditional graft rarely has flowers when it is released as a first year graft, the cutting-graft usually has several flowers so the customer can actually see what he is getting.

7. Finally, and most importantly for both the consumer and the nurserman, the cost is lower.