DEVELOPMENTS IN THE PROPAGATION AND NURSERY BUSINESS DURING THE PAST 46 YEARS

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To take you step by step or year by year through the tremendous changes that have occurred during my 46 years in contact with the propagation and nursery business would be cumbersome and take too much time. New ideas and information propagates rapidly and mutates frequently, and the original idea, like the first sprout from the acorn, may be overshadowed by later branches. Other horticulturists might select other events, but for my part I believe the following four are the ones that have given the phenomenal success rates in propagation that we experience today.

(1). In 1934 Professor Knudsen grew orchid seedlings on a sterile nutrient augar. From this small beginning came the study of plant tissues, knowledge on the use of auxins and other hormones, tissue culture propagation, and now to the point where we are doing genetic engineering.

(2). In 1951 the International Plant Propagators' Society was formed with its motto, "To Seek and to Share." No longer were propagation houses locked up, but new information was quickly shared with others. To this end we have to thank Jim Wells and others who helped bring the Society into being. The organization now has six Regions in the world.

(3). In 1957 we saw the publication of *Manual 23: The U. C. System of Growing Healthy Container-Grown Plants* (1). The editor was Kenneth F. Baker of the U. C. Plant Pathology Department.

(4). In 1959 we saw the publication of the first edition of *Plant Propagation: Principles and Practices* (2) with Hudson T. Hartmann and Dale E. Kester as co-authors.

These four events seem to me to have had a far greater effect on the field of propagation and growing of plants than merely the sum of the parts. This effect was not local in nature, but worldwide.

Before going further, I think it is important to point out that members of the Western Region of the International Plant Propagation Society were instrumental in the last two-mentioned events. When I talked with Dr. Baker he said that *Manual 23* could not have been written if he had not had the cooperation of the commercial nurserymen in southern California: Henry Ishida of the American Plant Growers, Carl Tasche of Union Nurseries, Bob Weidner of Buena Park Greenhouses and, of course, the lab work by O. A.

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Matkin of O. A. Matkin Soil and Plant Lab, Inc. Henry and Bob have been presidents of the IPPS Western Region, and Henry went on to be president of the International Board. All, incidentally, are charter members of the Western Region.

Both Dr. Hartmann and Dr. Kester were members of the original Eastern Region IPPS Society and became charter members when the Western Region was organized in December, 1960. It is interesting to note that the text, *Plant Propagation,* has been translated into five different languages, and in 1989 will come out with the fifth, revised edition. Since 1974 Dr. Hartmann has also served as editor of the *Combined Proceedings* of the six Regions. It is no small wonder the International Board has named him an honorary member.

In addition to the four big events there are thousands of other changes for the good, some of which I will mention. To simplify the presentation I have listed them under the following general headings: (1) information, (2) equipment, (3) materials, (4) techniques, (5) facilities, (6) markets.

(1). **Information.** The report of Dr. Knudsen's work in growing orchids in nutrient augar appeared in print in 1934. As a graduate in horticulture in 1936, with major interest in propagation, neither my professors nor I knew of it at that time. Today, with the computers, instant print-outs, and inter-library access, one can find in a matter of minutes just about everything of importance that has been written on a particular subject. The entering of new information into bibliographic data bases now occurs at the time of publication, which speeds up access to information by at least six months. The growth of the International Plant Propagators' Society is an indication of the great interest in access to information, and attendance at these meetings makes new information even more quickly available.

(2). **Equipment.** I believe this paper could be devoted alone to the many new pieces of equipment that have been invented and developed, but these are a few of the most important ones: the many carts, trailers and special vehicles that move our plant material from place to place; the canning machines that make it possible for a crew of 12 to pick up the cuttings, can-up the plants and place them in their new beds at a rate of 35,000 plants per day for an average of 2,916 plants per person; the movable benches which allow a 90 per cent use of greenhouse space rather than the old system of about 68 per cent; the equipment which allows us to not only water our plants automatically, but also to fertilize them at the same time—quite a change for tapping a pot with a nut on the end of a bamboo cane to determine if the plant needed water. Gone are the days of crews of men sweeping through the fields with their different-sized scoops. They did not always hit the container, or use the proper-sized scoop for fertilizer, or then hand-water each plant. How we have progressed through the different stages of mist. First, it was constant mist, timed-interval mist, electronic leaf, fog, and now high-pressure fog. I am sure I am missing a lot of the new mechanization, but time and space is limited.

(3). **Materials.** Perhaps the greatest change has been in our concept of potting soils. Prior to *Manual 23* some of the largest growers of interior plants had as many as 14 different soil mixes for the different plants they grew. One nursery I knew of had two acres of ground on which they composted their potting soil for nearly a year before use. They gathered oak leaves in the fall from mountain elevation above 4000 feet to be sure there would be no oak root fungus present. They got the manure from the race tracks, and they got their loam soil where available. This was layered, then turned and watered every month before use. The UC Mix was not the only one, but the Manual set forth the basic principles. Now there are many proprietary mixes that are available.

We have always had containers, originally clay pots or wooden boxes like those used in the Orangery at Versailles Palace circa 1689. A rim was added to keep the pots from jamming, and to indicate the proper level of potting. But how they accumulated alkaline and held disease, and they were so heavy! During World War II when there was a scarcity of containers, backyard nurserymen were putting plants in anything that would hold soil. Oil cans, then old #10 commercial cans, normally referred to as gallon cans, from hotels and restaurants were used. An improvement was the painting or tarring of these containers to prevent rust. Along came the plastic container, first round in the smaller sizes, which quickly changed to the square tapered pot that was manufactured so it exactly fitted the standard 18 inch flat. Today we have plastic containers in all shapes and sizes as well as plastic flats. The advantage is that they are lightweight, attractive, easily sterilized, and can be re-used many times. In addition to the above there are the new "plug" trays. Very often these are used in direct seeding and the plugs then transplanted to larger pots without the shock of bare-rooting. This has replaced the old soil blocks used so much in Europe. Now we have the new foam material where you stick your cutting into a prepared notched material that can be broken off after rooting and potted directly into a large container, again without the shock of transplanting.

Originally there was only peat moss to add as a soil conditioner, now we have perlite, fir bark, and a host of local materials that add aeration, improve drainage and, in some cases, hold moisture.

When I think of my early days of budding and grafting with raffia for binding and the complex formulae used in making grafting wax, I shudder. The raffia soon got too dry and unwrapped, or was not cut soon enough and the bud was girdled. The grafting wax did not have enough resin and melted in the sun, or it had too much beeswax and the bees actually cleaned the graft for the wax. Today we have the special budding rubber in all sizes. It is manufactured with an extra amount of sulfur in it so that the moisture from the plant forms a sulphurous acid that causes the rubber, under normal conditions, to disintegrate in about 15 days. Our grafting wax needs are taken care of with asphalt emulsion materials, such as Tree Seal and, if grafting boxes are used, it may not be necessary to use any grafting wax at all. I can remember visiting one nursery which covered each gallon can graft with a quart jar. As the graft began to grow the jars were tilted to allow a normalization of the humidity.

Who of you can remember blood meal, bone meal, cotton seed meal, and well-rotted manures? These have been replaced with balanced fertilizers of about any combination that you desire. Many of them are coated so that the nutrients are slowly released over a long period of time. These have been particularly useful as a final top dressing when the stock is sent to the retail nursery where the plants will not receive nutrients with the regular watering.

(4). **Techniques.** With our greater knowledge of how plants grow and what chemicals, auxins, and hormones will do it is possible to have our stock plants in optimum condition for propagation. No longer do nurseries take cuttings from plants in their display gardens, which weakens the plants, but they take the cuttings from young, vigorous container stock, and in this way are able to shape the plant for better appearance.

(5). **Facilities.** The old greenhouses are like pre-historic animals beside the efficient and automated, controlled houses of today. No longer is it necessary to send men hurrying through the houses to open top and side vents for sudden hot spells. The coating of the house with whitewash is out because the fiberglass that is used today is opaque and thus diffuses the sunlight. Fiberglass is also cheaper and easier to put up or replace. Today, with the pad and fan cooling, we control the temperatures in our houses for pennies a day, and the reaction time is practically instantaneous. Hot air heating with the large plastic tubes in the top of the houses is so responsive and uniform and so much cheaper to install than the old cast iron pipe under the benches. The fin tubing was an improvement over the cast iron, but the fins soon became coated with deposits, which decreased their efficiency. Using the hot air heating allows the use of the under-bench space for plants requiring low-light intensity. Though not used in propagation, one cannot discount the importance of the use of computers now in use in the horticultural industry.

(6). **Markets.** When the nurserymen realized their major competition was not the other nursery, but the merchants selling television sets, cars, cameras, and other items, real progress was being made. In the old days, sales in the nursery business was generally local in nature. Today we find that California, and principally Southern California, produces nearly 35 per cent of all the plant material grown in the USA. Climatic conditions there make it possible to grow and ship many types of plants year round cheaper and more reliably than the nurseries in other parts of the US. Shipments of plant materials out of the US have also shown an increase.

(7). **The Industry.** Without the propagator there could be no nursery business, no landscape contractors, no landscape architect. The home gardener would be hard put to take care of his needs, for where would his seed and plants come from? Gardening today is the biggest avocation or hobby in the United States. For many it is their recreation, and I like that word for it means "re creation," rejuvenation, or putting things in proper perspective. In 1820 in Leipzig, Germany, Dr. Shriver told the Town Council that people who lived in hotels and apartments had lost contact with the soil, plants, and God; that it was the responsibility for the cities to make available at a minimum cost a plot of ground where these people could re-establish their contacts with nature. Thus, the People's Gardens of Europe were established and continue to flourish even today. Despite many Europeans' lower income, higher taxes, and smaller yards, the horticultural use of plants is higher than in the USA. Mr. Ishizu of Sunnyslope Gardens in Pasadena, California told my class many years ago that there was a Japanese saying, "If you want to be happy for several hours, have a good meal. If you want to be happy for a weekend, get drunk. If you want to be happy for a week or more, get married. If you want to be happy all of your life, work with plants."

There are no finer people in the world than horticulturists. They have tolerance, understanding, and compassion. Some time ago Moto Asakawa of the Presidio Nursery in San Diego had a fire just before Christmas just after he had stocked his nursery for the big Christmas sales. The nurserymen of San Diego thought so much of Moto that they pooled their resources, helped him clear his parking area, put up a tent and put him back in business for the Christmas sales. Do you know of any other business that would have done more?

Below is a brief review of the nursery industry as given me by the California Nursery Association Executive Director, Jack Wick:

In 1940 there were 4017 nursery licenses in California. In 1985 there were 9030. Wholesale value in 1940 was $41,032,000 (no break-down of sales.) In 1985 the sales of nursery items in California amounted to $946,224,853, with an additional $291,465,915 in sales of cut flowers, foliage, and seed for a total of $1,237,690,768 ornamental horticultural sales.

One must remember that in 1940 the average gallon-can plant sold for 20.6 cents. Today the same cultivars sell for $2.45 which is

11.89 times more expensive. So if we multiply the 1940 sales by 11.89 and divide it into the total sales of 1985 we approach the approximate growth of the industry. There are many other factors to consider, but this will give us a rule-of-thumb estimate. It appears the nursery industry has grown 2.45 times the 1940 figure, disregarding inflation.

Horticulture has been a wonderful vocation for me. Although I might have made more money in some other field, I would have missed the fun and fellowship of men and women like IPPS members. Of all the organizations that I have belonged to over the years, there are none that I hold in higher esteem than the International Plant Propagators' Society with its motto, "To Seek and To Share."

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PLANT PRODUCTION BEHIND "THE REDWOOD CURTAIN"

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The geographical area referred to in this article includes only a portion of the internationally famous "Redwood Empire" of the state of California. But, it is a portion that is particularly unique. Rhododendrons, heathers, azaleas, and pieris thrive in this area.

The boundaries of this Northern California area include the entire coastline from Point Arena to Cape Mendocino. This is a land area resembling a bench. The ocean is to the west and a mountain range is a few miles to the east. Summer temperatures rarely exceed 75°F and the coldest winter temperatures normally do not drop below 15°F. A great portion of the area directly along the coast will not even have a frost. Giant redwoods [*Sequoia sempervirens* (D. Don) Endl.] have grown in this area for thousands of years.

Before the turn of the century, this entire coastal area was a vast grove of prime redwood. (Strangely, however, the initial major forest crop was tanbark.) In this area there were formerly many major lumber companies. Only a few survive today, the most promi-

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Before the turn of the century, this entire coastal area was a vast grove of prime redwood. (Strangely, however, the initial major forest crop was tanbark.) In this area there were formerly many major lumber companies. Only a few survive today, the most prominent being the Georgia-Pacific Corporation with a large mill in Fort Bragg. Previous owners of this mill were Boise-Cascade and the founding company, Union Lumber. This latter company was among the first firms in the area to produce woody plant material. They did have a tree farm of sorts, traces of which can yet be detected within the city of Fort Bragg. The person in charge of this early venture was Robert Cahoon, graduate of the University of Edinburgh, Scotland, and a former staff member of Kew Gardens, London. He experimented with many plants, including heathers, hollies, and cotoneasters. Evidence of his personal interest in these plants can be found scattered throughout the town of Fort Bragg, in the yards of some of the early homes built close to the big lumber mill.

Today, the area has nearly a dozen nursery growers producing plants for shipment into the San Francisco Bay Area and for sale to the visitor traffic which swarms to the Mendocino area to inspect the quaint houses, view the beautiful coast, and enjoy the cool weather. Among these growers are Fee's Rhododendrons, Descanso Nurseries, Lauer's Rhododendrons, Hopper Nursery, Heritage Rose Gardens, Richard's Nursery, Anderson Valley Nursery, Sherwood Nursery, and Fuchsiarama. The latter is an established retail grower specializing in fuchsias, operated by Howard and Linda Berry. Their trade is nearly exclusively from the inland area of the Sacramento Valley. Other retail growers and their specialties are: Heartwood Nursery, general ornamentals and camellias; Hare Creek Nursery, ornamentals including bedding plants; and Annabelle's, specializing in fuchsias, pelargoniums, and orchids.

But at first there was only the internationally famous Cottage Gardens Nursery of Eureka, California. Founded in 1913, the complete story of this great nursery would take many pages. We will simply refer to them as the pioneer commercial grower on the north coast of California. Founded by the Ward family of New York—and intended as a source for plant material for their Eastern retail nursery—the nursery was nurtured by the Causen brothers of Eureka, Ron and Otto. The Wards were initially lumber people from the Eureka area but the family relocated to the East Coast. Thus, the development and selection of material and marketing were left to the Causens, undisturbed by the firm's owners, who remained on the East Coast. Initial production included yews, boxwood, and bulbs. Cottage Gardens was the first firm in the west to successfully grow commercial crops of tuberous begonias from seed. Their techniques were later adopted by other growers in California located in the Monterey Bay area. But the success for which the firm is nationally renowned was in the growing of rhododendrons and azaleas. With both crops Cottage Gardens established a quality that represented the finest produced, and today nearly all growers in the west are conscious of being continually compared with the perfection Cottage Gardens achieved. The cultivars they selected to grow became the popular list and the sizes they finished became the standard sizes.

All of Cottage Gardens' azaleas and rhododendrons were grafted. And interestingly, they developed a system in Eureka whereby they prepared Christmas forcing azaleas that were completely dormant by early October of each year. By judicious pinching and reversing the normal growing procedures, they produced vegetative growth during the winter months and allowed the plants to go dormant during the summer months. This was accomplished without the benefit of refrigeration or growth retardants. Much of the material was shipped to the San Francisco Bay area to wholesale florists. Some of the larger firms received as many as 15,000 rhododendrons a year. Cottage Gardens also had a fling at camellias and introduced the famous *Camellia reticulata* cultivar, 'Captain Rawes' to the trade.

Today, Cottage Gardens is under new owners and is in the process of moving to the Napa, California area where the firm will specialize in tropical plants. Ron Causen, now a very senior citizen, still resides in Eureka in a house on property next to the old nursery. He feels that one of his most innovative accomplishments was the discovery that field-grown rhododendron plants could be satisfactorily transferred into containers and grown on to market size. Thus, while specializing in field-grown stock, they recognized the commercial convenience of container-grown plants, not those lifted and stuffed, and developed one of the first systems for this type of growing.

While Cottage Gardens has to be regarded as the first large commercial operation, and had no trouble maintaining this stature until the facility was sold in the late 60's, a pioneer commercial grower from southern California, a graduate of Cal Tech, and what is equally important, an apprentice at the famous Coolidge Rare Plant Gardens in Pasadena, California, John Druecker established what was to become the second largest nursery "behind the redwood curtain." Cal Tech graduates were not particularly sought after when John graduated in the early 1930's. He felt that a better opportunity was in the field of horticulture and soon went to work for the Coolidge establishment, at that time a recognized institution and perhaps the leading nursery in all of southern California, if not in the West. The pay was not notably good. On occasions it was "in kind." John came north in 1936 with plant material to establish his own nursery. He settled in the Fort Bragg area and his first efforts at commercial production were with forcing azaleas. This effort was not completely successful and during these early years of hard work, John and his wife Helen barely stayed solvent. By 1945 John had developed an interest in rhododendrons and aggressively sought new cultivars. Following the lead of Theo Van Veen of Oregon, he built a greenhouse with a mist system and commenced propagating the new cultivars he had acquired. Successful at propagation and growing, John developed a most interesting marketing system. He was aware of the success of the elegant rhododendron plants being distributed by Cottage Gardens Nursery, but he felt that a market must exist for well-grown but smaller material, at a lesser price. He developed a system of bed growing, under lath, of plants which he lifted after 2¼ years and offered as balled and burlapped material. His best customers were those firms which purchased material from Cottage. John always contended that Cottage Gardens was his best sales representative.

His success and good fortune in marketing his plants allowed John to leave the Fort Bragg area for months at a time during the winter and vacation in Mexico. During the time he spent in Mexico, he managed to do much plant exploring and, incidentally, made the acquaintance of other plant explorers which led to the discovery of several new species. A mahonia John found in Mexico was named after him, *M.* "Drueckerii."

John's procedure for propagation of rhododendrons was standard, though at the time he commenced his work it was all very new. His cuttings were stuck in late summer under mist. And because the climate in the Fort Bragg area is really not very stressful, John was absolutely confident that his new automatic system would take care of itself. The secret, John attests, was a new electronic controller which responded to intensity of light. This, plus the help of a few friends who "looked in", helped John to depart by Thanksgiving each year and be away for 90 days at a time. This practice continued for 27 years. Today, John is recognized as one of America's leading rhododendron plant breeders with twelve cultivars introduced to the commercial trade.

At present, John Druecker is retired, though his nursery continues to operate as Lauer's Rhododendrons, under the ownership of Mae Lauer.

At about the time that Cottage Gardens chose to discontinue production of rhododendrons and azaleas in the early 1960's, Descanso Nurseries commenced construction of a branch location in Fort Bragg. Descanso, like John Druecker, was also from southern California. Today, this nursery has approximately ten acres in production of a combination of plants, including rhododendrons, pieris, hydrangeas, heathers, daphnes, and other material that performs well in areas where summers are cool and winters are mild.

While it may appear that growers who have established commercial operations "behind the redwood curtain" have primarily been from southern California, several of the leading growers in the area moved over from the timber industry to the plant industry. Bill Fee and Bud Richards were both professional woodsmen. Fee's Rhododendrons was established in 1974 after Bill voluntarily retired from timber activities. His specialty is rhododendrons which are grown at his nursery of approximately three acres. He propagates all of his stock and, like Descanso, grows all of his plants in containers. A unique feature of Fee's operation is a water-saving irrigation system in which all plants of two gallon size and up are placed under spray stakes.

Bud Richards, a former professional woodsman and only recently retired from the Georgia-Pacific Corporation as superintendent of their greenhouse range at Fort Bragg, where seedling forest trees are raised, established his commercial nursery in 1955 while continuing to work in the woods. Initially, he produced rhododendrons, but his interest was soon attracted to deciduous azaleas which he grew from seed. After nearly 25 years of growing azaleas, Bud has developed his own strain of plants which he grows from his own selected seed parents. The feature of Richard's Nursery azaleas that is most noteworthy is that they require a minimum of winter chilling, and produce extraordinary large flowers in rich colors.

Two women growers operate commercial rhododendron nurseries in the Fort Bragg area—Mae Lauer and Lucille Hopper. Lauer's Rhododendrons was established in 1980 after purchasing the nursery from John Druecker. It remains on the original site alongside of Highway 20 leading into the town of Fort Bragg. The nursery site remains essentially unchanged from the day when it was operated by John Druecker, except that Mae Lauer no longer grows her plants in beds. All of her stock is container-grown. And like Fee's operation, she has developed an extensive system of spray stakes for watering her one gallon container plants which are the specialty of her nursery. Lauer is also an advocate of the use of "willow water" as a soak for cutting material and the incorporation of alfalfa meal in her potting and canning mixes. The willow water is manufactured by pulverizing the stems and foliage of willow trees and forming this into a brew. Cuttings are then soaked for a period of 8 to 12 hours in this mix prior to sticking. Lauer claims extraordinary success with difficult-to-root cultivars of rhododendrons such as 'King George' and others. The addition of alfalfa pellets (without molasses) to the potting/canning mix aids root development, claims Lauer. The alfalfa mix is used at a rate of no more than 5%.

Among problems affecting growers in the Fort Bragg area is locating material to use as a growing medium. Years ago growers' needs could be satisfied by harvesting the abundant supply of leaf mold that was always available. But as the wooded areas have become populated and access to the forest area where the leaf mold abounded is restricted, other materials were investigated for trial.

Locally, the lumber mills either burn their waste to generate power or manufacture "chips" which are trucked out of the area to other specialty mills. After much trial and error, the use of fir bark in the approximate size of 1/8 by 1/4, blended with 1/4 minus grade has proven to be most satisfactory. Ironically, this material must be trucked in from as far away as 350 miles, as there is no reliable local source.

Heritage Roses of Branscomb, California is owned and operated by Virginia Hopper and Gary and Joyce Demits. Their specialty is old-fashioned or "found" roses grown on their own roots. Heritage Roses offers up to 250 plant cultivars. Two years are needed to produce a crop. Plants are lifted the second winter after planting. Distribution of the Heritage Roses is retail mail order, with shipments made world-wide. This operation is quite unique for several reasons. First, their list of roses includes only plants from the 1900 to 1940 era, with some even earlier. Also, the location of the growing area is unusual in that it is in the cool fog belt of the north coast.

Howard Siebold, a retired hydraulic engineer and plant breeder, has achieved great distinction in his efforts to produce outstanding new tuberous begonia cultivars from seed. The internationally famous White Flower Farm, a mail order firm, has long relied on Siebold's distinctive material. His most recent efforts have resulted in the creation of fragrant tuberous begonias of which he has produced ten to date.

We have already mentioned that professional woodsmen in the area have turned to horticulture. One other is Bob Standley, owner and operator of the Noyo Tissue Culture Lab. Standley, a long-time sawyer in his family-owned shingle mill, has recently purchased the Noyo Tissue Culture Lab, founded by Dr. Hans Burkhardt, a former Cal Tech professor. Under Burkhardt, the lab specialized in custom tissue propagation of orchids. Dr. Burkhardt also invented a growing medium for the tissue culture of redwood trees which the forest industry considers a most noteworthy achievement. Standley intends to specialize in the production of tuberous begonias, particularly the new fragrant cultivars developed by his neighbor, Howard Siebold. The lab will continue working with orchids, lilies, and perhaps other new plant materials being developed by the several active hybridists and plant breeders of the area.

The largest grower on the coast behind the "redwood curtain," is the Georgia-Pacific Corporation. Their greenhouse range at Fort Bragg produces 2,000,000 trees each year. Most of these are used in Mendocino County for reforestation. The coastal redwood is the primary crop though about 400,000 Douglas fir are also grown. Mike Peterson is the manager of the Fort Bragg Tree Nursery. He reports that a primary interest of Georgia-Pacific is the production of a "superior" redwood. The firm has made a selection of about 200 trees and these are currently being evaluated and tested at the University of California at Davis.

Mike, a graduate of Humboldt State in Forestry, is another professional timber man who has personal interests in ornamental horticulture. Mike started his own nursery operation, Sherwood Nursery, in 1985 specializing in one gallon rhododendrons.

The Mendocino Coast Botanical Gardens just south of Fort Bragg on California Highway No. 1 was founded in the early 1960's by a retired southern California nurseryman, Ernest Schoeffer. He developed a 45-acre property into an attractive showplace and opened it to the public. Years later, Schoeffer sold the property and it was eventually acquired by the Mendocino Coast Recreation & Parks District and now leased to the non-profit "Botanical Gardens Preservation Corporation." A board of directors was established which includes many of the people mentioned in this article. A professional manager, Chet Boddy, was hired to direct the operation. Boddy has been able to combine the talents of the directors, many of whom are horticultural specialists, with local landscape architects such as Gary Ratway and with a large group of enthusiastic volunteers who do planting, weeding, grooming, tree work, etc. The Botanical Gardens is not funded in any manner. It must pay its own way for development and maintenance. And with the magnificent display of perennials, many of which are new to the trade, in a landscape setting of rhododendrons, azaleas, and camellias, the Gardens has attracted many visitors and much acclaimed attention.

The Gardens boasts of the largest heather collection on the north coast, a large ivy collection, and extensive planting of rhododendron species. This past year, the number of visitors to the Gardens exceeded 25,000.

This overview of horticultural activities and opportunities "behind the Redwood Curtain" was prepared with the view in mind of demonstrating the adaptability of this remote area to commercial horticulture and how it is possible for those with determination and vision to accomplish a satisfactory degree of success.

EFFECT OF IRRIGATION METHOD ON PLANT GROWTH AND WATER USE

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Interest in water use for nursery production in Oregon became acute in 1977 when Water Masters in some districts started enforcing a 1909 law following the dry 1976–77 winter season. This law states that 30 acre-inches can be used during the irrigation season from April 1 to September 30 with a standard water rights permit. Water for commercial use, a separate permit which could include nursery use, is not restricted but has a lower priority in case of a water shortage.

To find out how much water was used by Oregon nurseries, a survey was conducted of six crop groups by Bluhm, et al (2) in 1978 and 1979. Water use in acre-inches was: container nurserystock 53–170, forcing azaleas 86–114, miscellaneous greenhouse crops 33–87, field rhododendrons 19–36, deciduous trees 21–34, and conifer seedlings 8–164. Summer cooling and frost protection were responsible for the very high use in container nurserystock and conifer seedlings.

Water use in container production always exceeded 30 acre-inches and the acreage grown was much larger than other high users so this was the area needing research first. Water use in 3 gal. and larger containers is reduced with drip irrigation in many California nurseries but drip irrigation is not practical for smaller containers. In Europe where energy and water costs are high, sand beds and capillary matting are used for irrigation (3, 6). Trials in the U.S. have shown reduced water consumption and better growth with capillary irrigation (1, 4, 5).

Two level sand beds 7 × 30 ft. were constructed during 1982 using an Irish design. The beds were framed with 2 × 6 in. lumber and lined with 6 mil black polyethylene. A 4 in. tile in the bottom of the bed distributes water during the growing season and serves as a drain line when the plastic liner at end of the bed is lowered so the tile can be connected to a field drain during the rainy season. Water level is maintained 1 in. below the Mason sand (fine sand) surface by a stock tank float valve which requires no power. Water use by this system and by sprinkler irrigation with and without a tensiometer override were measured by water meters (Table 1).

A sloped (1 ft. fall in 78 ft.) sand capillary bed with 2 × 4 in. wooden check dams for each 2 in. fall was constructed in 1984. Water application through two drip lines was controlled by a "Water Bug", (Flowering Plants Ltd. England). The "Water Bug"

Table 1. Water use June through October, in inches, with several irrigation methods, 1983–85.

	1983	1984	1985
Level capillary sand bed	16.3	19.3	23.8
Sloped* capillary sand bed	—	—	24.9
Overhead irrigation	93.1	100.3	115.2
Overhead with tensiometer override	75.7	—	—

*Water Bug Control—Flowering Plants Limited

electronically senses the moisture content of the sand to determine when and how much water to apply.

Two potting mixes, 70 peat:30 fine sand, and 90 bark (½ in. minus):10 fine sand by volume were used in 1982 and 1983. Nitrogen at 1 lb per yd.^{3} from Osmocote 17-7-12 was used with both media in 1982. In 1983 and later years, the level of N was raised to 1.8 lbs per yd^3 of bark medium.

Two products, Gloquat "C", a quaternary ammonium chloride from England, and the herbicide Oryzalin-Surflan were used to control the major problems with out-of-door sand beds—weeds and emerging roots. Some plants, such as forsythia, which will root in water should not be grown on capillary beds but are good indicator plants for root control trials.

Test plants used in 1982 and 1983 were *Chamaecyparis lawsoniana* 'Ellwoodii' and *Erica erigena* (Syn. *E. mediterranea*), both of which are susceptible to root rot diseases. No root rot has developed in five years of operation. A number of other genera have been used since then including *Forsythia, Ilex, Juniperus, Photinia, Prunus, Rhododendron,* and *Viburnum.*

RESULTS

pRooted cuttings planted in 4 in. or 1 gal. containers in 1982 were shifted to 1 gal. and 3 gal. containers, respectively, for 1983. Height and width of Ellwood cypress and width of the heath were significantly greater with capillary irrigation than either overhead system. Plants grown in 70 peat:30 sand were larger and heavier than in 90 bark:10 sand, even with the increased level of nitrogen in the bark mix when they were shifted.

New heath cuttings potted in 1983 in bark:sand mix were larger with overhead irrigation than those in either bark:sand or peat:sand, with capillary irrigation. High salinity is the probable explanation for the decreased growth in 1983.

Trials in 1985 (Tables 2 and 3) were designed to evaluate pot type (solid or mesh) bottoms, chemical root control, and irrigation system on the growth and flowering of *Forsythia* × *intermedia* 'Lynwood'. Mesh bottom pots establish capillarity readily but also permit extensive undesirable root development outside of the pot. Gloquat "C" was the most effective root restricting treatment for

Table 2. Growth of *Forsythia* × *intermedia* 'Lynwood' as influenced by irrigation method and root control treatment, 1985.

Irrigation method	Root treatment	Height (cms)	Width (cms)	Number of branches	Fresh weight of emerged roots grams	Number of flowers nodes
Level	Check	70.5a	62.1a	22.5a	88.0b	74.0bc
capillary	Gloquat "C"	63.7ab	57.6ab	24.7a	15.2a	76.1bc
bed	Surflan	66.5ab	62.1a	22.9a	85.2b	65.4c
Sloped	Check	66.9ab	51.7bc	16.9b	175.6c	90.3ab
capillary	Gloquat "C"	59.0b	46.0c	16.3b	39.0a	97.9a
bed	Surflan	64.6a	49.4c	16.5b	166.3c	93.9ab

Numbers in a column followed by the same letters are not significantly different. Duncan's Multiple Range Test, 5%.

Table 3. Influence of irrigation method and pot type (solid or mesh bottoms) on growth of *Forsythia* × *intermedia* 'Lynwood', 1985.

Irrigation method	Pot type	Height (cms)	Width (cms)	Number of branches	Fresh weight of emerged roots grams	Number of flower nodes
Sprinkler	Solid	41.4c	40.0	24.7a	0.1a	110.3a
	Mesh	52.0bc	36.0d	24.4a	44.1ab	100.4ab
Level	Solid	71.9a	60.3ab	21.9a	72.3bc	61.8c
capillary bed	Mesh	69.0a	64.0a	23.2a	103.6cd	71.1bc
Sloped	Solid	62.2ab	49.1bcd	14.3b	148.1de	84.6abc
capillary bed	Mesh	67.7a	54.3abc	19.4ab	203.1e	96.1abc

capillary beds and provided longer weed control in the sand bed than Surflan. Weed and root control with Surflan was variable and in some trials was more effective than in the 1985 test. Plants were smaller but had more flower buds with sprinkler than capillary irrigation.

It was possible to grow plants in 4 in. to 3 gal. pots on the same capillary bed. With overhead irrigation, it is necessary to irrigate for the plant with the greatest water need and the other plants may receive excess water. The tensiometer override did reduce water use over a manually set time clock but did require some manual turning on when plants started to wilt in the porous media. Growth was also reduced with the tensiometer.

Water use with capillary irrigation was about 1/5 that of sprinkler application so it is possible to grow container nursery-stock with 30 acre-inches of water or less. Water use for capillary irrigation closely parallels evaporation from a free water surface.

Capillary irrigation does provide a method to use less water and to reduce use and run-off of fertilizers and other agricultural chemicals. In most cases growth will be as large or larger than with plants grown with overhead irrigation.

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PERLITE: START TO FINISH

GREG MOORE

REDCO II

11831 Vose Street

North Hollywood, California 91605

Few propagation mixes today are devoid of at least some perlite and so this common tie deserves elaboration. We will first identify its origins and processing and then examine how perlite uniquely meets traditional grower applications, with a passing comparison to several other inorganic amendments.

Origins—Perlite is found worldwide as a naturally occurring igneous glassy rock (an amorphous silicate) similar to obsidian and rhyolite. It is distinguished from them by possessing 2 to 6% combined water collected from free surface or atmospheric moisture present as it cooled. The raw rock ranges from translucent to gray or black and is quite friable, with a loose density of 60 to 70 lbs./ft.^{3}.

Perlite ore is generally surface mined via tractor ripping and scraping. The ore is then crushed, dried and screened, to size segregate it, before being transported by truck, railcar, or barge to expansion plants.

Processing—Precision expansion of a variety of finished products is achieved by proper selection of ore size, furnace draft and temperature. Processing consists of heating the ore from between 1100° to 1600°F, so that, while the outer kernel softens, the bound water abruptly flashes to steam and is released from the chemicals. In most cases growth will be as large or larger than with plants grown with overhead irrigation.

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Processing—Precision expansion of a variety of finished products is achieved by proper selection of ore size, furnace draft and temperature. Processing consists of heating the ore from between 1100° to 1600°F, so that, while the outer kernel softens, the bound water abruptly flashes to steam and is released from the mineral, thereby expanding the particle to a lightweight collection of glass-sealed bubbles. Expanded perlite density is geared to end use need, including industrial and construction, and ranges in density between 2 to 12 lbs./ft.^{3}, and in size from −300 mesh to ½ in. Coarser ore produces coarser perlite (and finer by-products) and, everything else being equal, it is generally to the expander's advantage to expand ore at lower density because there is a larger expanded yield per unit of raw ore, e.g. 2,000 lbs. ore expanded at 5 lbs./ft.^{3} yields 400 ft.^{3}, while the same unit of ore expanded at 7 lbs./ft.^{3} yields only 285 ft.^{3}. This is important to the nursery grower since 7 lbs./ft.^{3} perlite is harder, and better maintains its integrity in mixing and long term growing, i.e. without a collapse in air space from soft perlite engendered fines.

Packaging and Delivery—Expanded perlite is packaged in a wide variety of paper, polyethylene, or returnable muslin or dacron bags, ranging in size from less than 1 ft.^{3} to 2 yds.^{3} For those with provisions to receive it (primarily closed systems or plenty of water spray) it is sold in bulk tanks or dumpsters.

Advantage of the increasingly popular returnable (particularly large sized) bags include the minimization or elimination of such hidden costs associated with throw-away paper bag use as: 1) higher intrinsic bag costs, 2) higher handling costs, 3) broken bags due to handling, or the necessity of outdoor storage in inclement weather, 4) loss of material in the vacuum formed in the unbroken, unemptied part of each broken paper bag, 5) trash removal costs, and 6) the difficulty of water treating perlite (one of our routine procedures for dust control) in paper bags (unless more expensive lined paper bags are used.)

Horticultural properties of perlite.

1) Perlite is readily available in a wide variety of grades, with worldwide reproducibility and excellent compatibility with the full range of organic and inorganic mix ingredients.

2) With its inherent porosity, it is very lightweight, usually 5 to 8 lbs./ft.^{3} (or 80 to 128 Kg/m^3) and it is easy, safe, and inexpensive to handle, transport, and use in mixes. For example, its use minimizes losses when pricking out or transplanting since the lightweight root system remains intact on removal; similarly, it allows new dimensions in hanging baskets and rooftop gardens, vis-a-vis soil-based mixes.

3) It is axiomatic that plant roots need ample oxygen for root respiration, gas exchange, and overall good rooting with minimal damage or disease. Perlite is rightly perceived principally as an aerator; in fact, in Japan perlite is called "Nenisanso", meaning "giving oxygen to the roots". With its inherent sharpness it provides excellent particle interference, thus generating voids or macropore space, which allows excess moisture to drain away. Moreover, perlite creates a very favorable balance between aeration and water

retention because perlite has an immense and unique surface area configuration which adsorbs water and water soluble nutrients in the micropore space, for subsequent easy release. Since particle size distribution affects soil pore size, mixes with coarser perlite generally have a greater air to water ratio than mixes with finer grades, and thus provide greater oxygen availability (even when fully saturated, as at field capacity), oxygen diffusion rate, drainage and leaching of excess soluble salts. The mixture, however, of relatively coarse perlite with fine organic particles can allow interstitial marrying of the two, thus filling to some extent the macropore space, and permitting excessive sogginess. Conversely, *uniformly* fine perlite, if sized with the proper organics, can drain well and provide good oxygen availability. To minimize particle segregation and degradation in mixing, perlite can be mixed slightly wet, with a low shear ribbon or paddle type mixer and with as short a mixing time as possible.

4) Perlite is inorganic, but not a by-product and not artificial and it does not appreciably, even in fumigation, deteriorate, shrink, or compact.

5) Perlite is chemically inert, pH neutral, sterile, odorless, and free of foreign material. With its known low CEC and salinity, it provides an excellent starting point for control of plant nutrition. The corollary is that it is less forgiving of nutrient starvation or excess than soil, and perlite substrates generally require constant liquid feed or slow-release fertilizers. A note regarding fluoride and perlite: Some perlite ores have small amounts of fluoride, and for those few plants sensitive to fluoride, the elimination of superphosphate (which contributes fluoride), or the addition of extra calcium to form a CaFl precipitate, which will leave little soluble fluoride.

6) Perlite imparts excellent soil temperature insulation (with its closed cell structure) by moderating temperature fluctuations—an *especially valuable contribution in seed and cutting propagation.*

7) Perlite acts as a reflector of light from the top of the soil surface up to the foliage underside, which is especially useful in low light areas and in fall and winter.

8) Perlite is easy to wet for dust control and, dry or wet, it is a trouble-free performer in automatic mixing and tray filling equipment.

9) Perlite is often used as a seedcoat ingredient to enhance seed appearance, sowing, and germination.

Specific Usages:

Cutting propagation—Perlite, although used in the full range of propagated plants, finds its best use with semi-hardwood cuttings, where long term misting occurs and high aeration and drainage are required. Typical cutting mixes for semi-hard or hardwood cuttings incorporate 30 to 100% perlite—most commonly 80 to 90% (up to

100% if slightly finer perlite is used to substitute for peat moss). With its optimum balance of air and water, it provides excellent rooting, minimizing compaction, sogginess and decay as well as damping-off risk. Moreover, cuttings are easily removed after rooting without root damage, thus lessening transplant shock and enabling rooted cuttings to get a faster start. In soft stem and leaf cuttings, particularly groundcovers, perlite is used at between 20 to 80% (usually 30 to 60%), most often with peat moss.

General Seeding and Bedding Plant Seeding and Growing. Perlite encourages quicker seed germination and seedling growth with less check in growth upon pricking out or potting on; 20 to 50% perlite is typically incorporated with peat, vermiculite, wood residuals and/or sand, topped with a mulch (of any of these) to provide easy re-wetting without surface capping.

Canning—Perlite has long been a mainstay (used at 20 to 60%) in the production of potted plants, indoor foliage, general ornamental liners, and canned azaleas/camellias to improve and maintain the aeration, drainage, leachability, rewettability, and lightweight of the mix. Coarse perlite is often used here but finer grades can be mixed with soil and/or peat to provide an easy to mix and pot medium that is cohesive and provides good root branching. Care must be taken if finer grades are used in liners, since the extra water retention is multiplied with liners' higher zone of capillarity. Also, care must be taken to avoid liner shift-up from heavy to light mixes since new roots will not easily penetrate the heavier surrounding soil. In the future, perlite may gain wider acceptance in general ornamental nursery stock at 5 to 15% (by volume) to minimize sand compaction and stratification, to facilitate handling in the nursery, and to lower shipping costs, and to increase water retention for warm climate retail outlets.

Soil Conditioners—When incorporated by spading or rototilling, with or without organic matter, perlite aerifies and loosens clay soil and improves the water and nutrient holding ability of sandy soil (finer grades especially). It is particularly valuable in poorly drained or compacted areas such as golf greens and athletic fields where it helps bring marginal sands (i.e., too coarse, fine, or silty) closer to USGA specifications.

In this and in general use, it also promotes easier leaching and adds a measure of drought insurance, while reducing stratification, surface crusting, and traffic-induced compaction. It can be added to all phases of soil preparation, including soil or green reconstruction and sod aerification/plugging—including top dressing, (watered or raked in).

Specialty Applications include:

a) Carrier for wetting agent, fertilizer, pesticides.

b) Bulb, corm or tuber storage.

c) Recirculating and non-recirculating quasi-hypoponic bag systems.

d) In ring culture, capillary benching, growing bags.

e) Mushroom casing additives.

f) Sewage sludge compost additive where it absorbs excess water and improves air flow, thus enhancing composting. It is also useful in the final product as an amendment.

Inorganic Comparisons—No discussion of perlite would be complete without at least passing reference to the other most common inorganic amendments that it is often used in conjunction with or in lieu of. One of the salient features of perlite is its high total porosity, i.e. the total available for occupation by water and air. This is largely so because the inner air space of perlite is not entirely occupied, while the inner air space of sand, pumice and polystyrene (despite their radically different densities) are relatively more solid or occupied. With respect to total porosity, only coarse vermiculite (with 80% + and with air space of 43%) and peat (with 80% +) have more than coarse perlite (with 70% +, and air space of 60%) while sand varies from 30 to 45%. Perlite holds 2 to 4 times its dry weight of water while sand and polystyrene hold considerably less, whereas peat and vermiculite hold far more.

TOP-WORKING (WINTER-FIELD GRAFTING)

F. ALLAN ELLIOTT

Carlton Plants
14301 S. E. Wallace Road
Dayton, Oregon 97114

One of the methods of propagation used at Carlton Plants is that of top-working or winter-field grafting. This technique is used in combination with other methods of propagation to develop a unique style of tree. This style or form is characterized by having a clean straight trunk to a specific height, then a burst of limbs and foliage from that point. A select group of plants lend themselves to top-working, specifically those with a compact globular form and those that are weeping. Other advantages to top-working are to circumvent the problems of poor bud take and slow growth rates of some cultivars.

Cultivars. Current production levels consist of about twenty cultivars totaling 50,000 plants. The majority of this production is in flowering cherries with the remainder being globular and pendulus forms of ornamental tree, (See Table 1).

Materials. The grafting process requires some basic tools and supplies. Those used at Carlton consist of a good knife, sharpening stone, leather strap, hand pruners, and pouch to carry scionwood. Other supplies include 1 in. wide paint brush, tree tar, 1 in. wide

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Table 1. Explanation of various rootstock, interstem and graft combinations used

Scion cultivar	Rootstock/ interstem	Schedule	Graft Height	Graft Type
Acer platanoides 'Globosum'	*Acer platanoides*	2	6′	cleft
Caragana arborescens var. *pendula*	*Caragana arborescens*	2	3′	cleft
Caragana arborescens 'Walker'	*Caragana arborescens*	2	3′	cleft
Cercidiphyllum japonicum 'Pendulum'	*Cercidiphyllum japonicum*	2	5′	cleft
Corylus avellana 'Contorta'	*Corylus avellana*	2	3′	cleft
Laburnum alpinum forma *pendulum*	*Laburnum anagyroides*	2	4′ & 5′	cleft
Malus 'Coralburst'	*Malus pumila*	2	3′	cleft
Malus 'Sargen Tina'	interstem-white flower crabapple	2	4′	cleft
Morus alba 'Pendula'	*Morus alba*	2	4′ & 5′	cleft
Prunus × *cistena*	*Prunus cerasifera* Mgro-29C interstem-*P. cerasifera* 'Newport'	2	3, 4½, 5½	cleft whip or tongue
Prunus 'Accolade'	*Prunus avium*	2	6′	cleft
Prunus × *yedoensis* 'Akebono'	*Prunus avium*	2	6′	and/ or
Prunus serrulata 'Shirotae' ['Mount Fuji']	*Prunus avium*	2	6′	whip & tongue
Prunus serrulata 'Shirofugen'	*Prunus avium*	2	6′	"
Prunus serrulata 'Kwanzan'	*Prunus avium*	2	6′	"
Prunus 'Snow Fountain'®	*Prunus avium*	2	4½′	"
Prunus subhirtella 'Autumnalis'	*Prunus avium*	2	6′	"
Prunus subhirtella 'Pendula'	*Prunus avium*	2	3′ & 5½′	"
Prunus × *yedoensis* "Yoshino"	*Prunus avium*	2	6′	"
Robinia pseudoacacia 'Umbraculifera'	*Robinia pseudoacacia*	1	6′	cleft
Salix caprea 'Pendula'	*Salix caprea*	1	4′ & 5′	cleft
Syringa meyeri	*Syringa reticulata*	2	3′	cleft
Ulmus glabra 'Camperdown'	*Ulmus pumila*	1	base, 5½′	bark, cleft
Wisteria sinensis (purple, blue, pink, white)	*Wisteria sinensis*	1, 2	base, 5½′	cleft

surveyors' tape, and a 6 ft. tape measure.

Scion Orchards. *Carlton maintains an extensive scion orchard* or mother block for the production of high quality budding and grafting wood. These orchards are severely pruned once a year in fall or winter to concentrate grow for the following season. Fertilization takes place in the spring with ammonium nitrate at about 400 lb. per acre. Sprays for insects and disease are applied *throughout the season. Irrigation is withheld in the fall on established* trees to allow the wood to mature properly.

Scionwood. Scionwood is collected about December 15th. Working with this date allows time for collection prior to our coldest weather, a time when damage to the buds can occur.

Wood is always selected from current season's growth. Shoots are cut long (3 ft.) to prevent dehydration which occurs with small sticks. The caliper of most scions is in the range of ¼ to ½ in. in diameter. One should review the size of the rootstocks to be grafted in order to select the proper size of scionwood.

Once cut, the limbs are brought into a building where they are graded, counted, packaged, and labeled for storage.

The bundles of wood are either wrapped in butchers' paper or placed in poly bags for storage.

The quantity of scions is estimated and registered, then the packages are placed in a cooler for storage at 36°F.

Rootstocks and Interstems. When choosing the rootstock and/or interstem, consideration must be given to compatibility and hardiness. Table 1 shows the rootstock that is used with each scion cultivar. Producing the rootstock/interstem to be top-worked is handled two ways on two different schedules.

One-Year Schedule. . . .

The seedling or rooted cutting is planted out in April and May. Once the plant has established roots and has started to grow, the plant is cut back to a single bud or shoot. The plant concentrates all its energy into a single stem which grows rapidly. The plant is staked and then tied throughout the season. Nitrogen fertilizer is applied in mid-July. The plants are cultivated and irrigated and continue growing. The growth obtained varies with each cultivar; however, 5 to 6-foot plants can be obtained in one season. See Table 1 for growing schedule for each rootstock and interstem.

Two-Year Schedule. . . .

On this schedule, the seedling or rooted cutting is again spring-planted. The plant is irrigated and cultivated through the summer. In August some rootstocks (such as *Prunus* and *Malus*) are budded. In about 30 days, the bud bands are cut and the bud lays dormant until the following spring. The remaining rootstocks not handled in this manner are allowed to continue growing untouched to build roots and caliper. In March of the following season, the tops of the rootstocks are cut back to a bud. At this point, the plants are staked, tied, and maintained as in the one-year schedule. The rootstocks go dormant in fall and are untouched until time of grafting the next year.

Timing. The grafting is done February 15th through March 15th. Some regrafting is done about April 1st. At this time, there is activity within the plant but no growth is apparent. Grafting is only done on dry days.

Grafting heights. The height at which the various cultivars are grafted is dictated by factors such as growth rate, eventual use, aesthetics, and customer demand. Grafting heights for each cultivar are listed in Table 1.

The top-working process. To streamline the process, 3 workers are used as a team. They start with one person cutting the tops off of the rootstocks at the desired height and removing any side limbs. Cull plants are also removed at this time. The other two workers sort through the scionwood and cut scions, usually 6 to 8 in. long from the bundle of long whips taken from storage. The scions are put into a pouch which the grafter wears at his waist. The three workers take their place in a row with the grafter in front. The grafter first makes the cuts on the scion, leaving 4 to 6 buds per stick. The appropriate cut is then made on the top of the rootstock and the scion inserted to match the cambium layers.

The second worker's job is to wrap the graft union. This is done using a strip of 1 in. wide surveyors tape. The wrap is started on the rootstock and worked up about 1 in. onto the scion, then tied off. The third person paints the top of the scion and the area just above the tape on the scion. This is done with a 1 in. wide paint brush and tree wound tar. This process is repeated some 600 to 800 times a day for each crew. Three basic grafts are used depending on the cultivars. They are the cleft, whip and tongue, and bark grafts. Table 1. indicates the graft used for each cultivar.

Aftercare. The grafts are watched for signs of growth. Buds usually start to swell in 4 to 6 weeks. Those that appear dry and shriveled may be regrafted. By mid-April buds break and begin growing on both rootstock and scion. All shoots on the rootstock are removed except for about 4 to 6 just below the graft. These are called pullers and are left in place to help nourish the plant until the scion is established. They are removed when about 6 to 8 in. long.

The tape is left in place for 3 to 4 months to give support to the graft union. It is removed by cutting with a sharp knife.

The plants are fertilized twice and cultivated and irrigated on a regular basis throughout the season. Some balancing of the limbs is necessary to make a full and balanced canopy.

Finished product. The trees will have taken on shape and character by season's end. They are dug from the soil bareroot and brought to the warehouse for grading, storage and eventual shipment.

PROACTIVE STRATEGIES TO MEDIATE TREE-ROOT DAMAGE TO SIDEWALKS

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Tree-root damage to sidewalks along urban streets is a pervasive problem. To meet the desires of their residents for shade and aesthetics, cities have traditionally lined their streets with trees. This practice has received strong endorsement from the residents as well as the nursery industry.

As trees mature, they frequently cause insidious but widespread destruction to adjacent sidewalks. Contrary to popular belief, the soil environment beneath sidewalks apparently favors tree-root growth. The sidewalk, made of concrete, functions as a barrier against soil moisture loss by either evaporation or transpiration. In addition, the high moisture content of the soil, compared to the concrete, confers upon the soil a high specific heat. When the sidewalk warms, some of the heat radiates to the soil beneath it. Conversely, when the sidewalk cools, the temperature drops more rapidly than the soil, and the underside of the sidewalk becomes a surface for condensation of soil moisture which subsequently percolates back into the soil.

Tree roots tend to grow where the soil environment is most favorable and, therefore, often grow at very shallow depths as they extend under a siewalk. These shallow roots, which, like all roots, enlarge radially, eventually may cause upward displacement of adjacent sidewalks. Typically, the displacement is uneven and "lips" may be created where adjoining sections of sidewalk are differentially lifted. Pedestrians, failing to see these lips, may trip over them and be injured. Replacement by cities of displaced sections of sidewalk becomes necessary to prevent pedestrian accidents and litigation by injured victims. Yet, like ocean waves repeatedly pounding a beach, the roots which are cut back during sidwalk replacement, invariably regenerate and repeat their destruction, necessitating cyclical sidewalk repair.

Besides the foregoing strategy in dealing with the problem, various types of plastic barriers have become available but their longterm benefit is unknown. Another practice, often advocated, is thorough watering of young trees to prevent a moisture differential in the soil profile which might favor shallow rooting. Notwithstanding the soundness of proper watering to promote tree survival and growth, I know of no proof that urban trees are, indeed, under-

[1] Trade names and commercial products or enterprises are mentioned solely for *information. No endorsement by the USDA Forest Service is implied.*

watered. It is possible that shallow rooting is more a manifestation of genetics than environment. Moreover, even if trees are underwatered and shallow rooting the consequence, there is a question of whether enough urban residents could be "reformed" in their tree-watering practices to have a significant impact.

Apart from current practices, there undoubtedly are other ways that would be cost-effective and feasible of implementation to mediate or even prevent this tree root/sidewalk conflict. Much of my research in recent years has been directed towards identifying such remedies. Among the possibilities under study, some that may depend on implementation by the nursery industry are described below.

Species That Best Fit the Space. The problem of sidewalk damage by tree roots occurs mostly along streets where the trees are located in the strip of land that separates a curb and sidewalk. This space, referred to as the treelawn, planting strip, or parking strip, may be from 2 to 8 feet wide, differing markedly among geographic regions (4).

Wagar and Barker (9) found that in the East Bay Area of San Francisco, where 3- and 4-foot-wide treelawns predominate, sidewalk damage was least with smaller tree species, such as cultivars of purpleleaf plum (*Prunus cerasifera*). It was most serious, as expected, with the most abundant, large-sized species, such as the popular sweetgum (*Liquidambar styraciflua*).

Why are the most frequently planted trees often the kinds destined to do the most sidewalk damage and, therefore, the most expensive to maintain during their lifetime? A primary reason seems to be the widespread availability of these kinds of trees and, conversely, lack of trees that are of conservative size.

Among conservative or moderate-size tree species that should be best suited for use in narrow treelawns, few are readily available from nurseries. An example is the durable European hornbeam (*Carpinus betulus*), a species which apparently is adapted to a wide range of environments. Moderate in size, European hornbeam grows at a moderate rather than a rapid rate and so should need no excessive pruning. It has tough wood that withstands strong winds and other load stresses, and it is virtually pest-free. Moreover, its fruit is dry at maturity and so not messy when it falls, as is fleshy fruit.

Any European hornbeam trees available in the past predominately have been selections with narrow or fastigiate crowns. Such trees may be popular as accents in the landscape, but selections with either globular or pyramidal crowns should be better suited for use along streets where shade is a critical feature. Other traits of this species meriting attention while selecting for crown form include autumn instead of late-winter defoliation, absence of fruit (2), trunks free of suckers, and bark resistant to sunburn.

Indeed, genetic improvement of trees to enhance their usefulness in urban areas would be desirable for most tree species. *Tristania laurina*, sometimes called swamp gum but usually known by its scientific name, for example, is another promising, moderate-size species, except for its fruit. Residents of a street lined with this species in Albany, California, object to the unpleasant, musty odor inside their cars when the clove-like fruit from these trees decays after falling into the cars' air vents. Clearly, a non-fruiting selection would be distinctly superior.

A flawed "delivery system" which fails to dovetail production capability with consumer needs, may be the reason why moderate-size tree species or unique selections of them, instead of larger-size species, are not extensively planted in narrow treelawns. Cost can hardly be a reason because a city should easily justify paying a surcharge, if need be, for such trees, with the expectation that this added cost would be offset by lower maintenance costs during the lifetime of the tree.

Since damage to sidewalks is preceded by shallow root growth, keeping roots away from sidewalks, or as deep as possible when they pass under the sidewalk should be a key objective. Among various strategies that may effectively separate tree roots from sidewalks, one strategy is the promotion of extra-deep rooting, given favorable soil conditions (3). Possibilities for promoting deep-rooting include (a) species with inherently deep roots, (b) unique phenotypes with unusually deep roots, or (c) trees whose roots are molded, during nursery production, into a columnar rootball to facilitate planting the roots that are at the bottom of the root ball exceptionally deep.

Deep-Rooted Species. Differences in massiveness and depth of the root systems are common among tree species. Krasilnikov (7) subdivided woody plant root systems into 11 classes according to their usual depth. The morphological extremes of this classification are tap-rooted trees and shallow-rooted trees. Tap-rooted trees would be expected to have the fewest shallow roots and, therefore, when grown along urban streets, do least damage to sidewalks. Unfortunately, for an array of tree species that may be used in cities, there is a paucity of information about their root morphology. The classification of each species into one or more of Krasilnikov's classes, therefore, is dependent on further study of their root morphology.

Unique Phenotypes. Just as trees of a species have variable crowns, so, too, may their root systems differ. Such variation was obvious when I excavated 8 maturing Chinese hackberry (*Celtis sinensis*) trees along a freeway near Davis, California. Within the excavation zone, which was an area 4 feet radius from trunk center and 15 in. deep, the roots of one of the trees were unusually massive, a condition that was not apparent above ground. In contrast, at the other extreme, another tree had relatively few and much smaller roots. Had there been a sidewalk adjacent to these two trees, the probability of its being damaged undoubtedly would be greatest for the tree with the massive roots.

Examining the roots of maturing trees, like the ones mentioned above, to locate promising root systems for vegetative propagation and possible use as clonal rootstock, requires more labor than is practical. An alternative method, used by Bowman (5) and Kormanik (6), is to screen bare-root nursery stock. Using this method, I have observed dramatic differences in the rooting pattern of 2- to 5-year old seedlings of sweetgum, European and Chinese hackberry (*Celtis australis, C. sinensis*), golden-raintree (*Koelreuteria paniculata*), and other species. The significance of some of these differences is being determined by field experiments now in progress. The objective is to determine whether young seedling trees with steeply descending roots develop exceptionally deep root systems in the landscape.

Other field experiments are examining differences in root morphology between tissue-cultured clones of two 35-year-old sweetgum trees. These parent trees, which technically are the ortets of the tissue-cultured clones or ramets, are located about 40 feet apart along a street in Oakland, California, and have contrasting root systems. On one of these trees, there is pronounced trunk flare, or rather a massive part of the root system is exposed above ground, and the adjacent sidewalk has been replaced three times. The other tree has little trunk flare, no roots show above ground, and the adjacent sidewalk has relatively little damage.

Columnar Rootball. An alternative strategy for promoting exceptionally deep rooting of trees may be to set the roots extra deep when the trees are planted. For this purpose, I grow trees in extra-deep containers, as Amling (1) did with pecans. In this sleeve container, which measures 30 inches deep and 7 inches in diameter, I produce columnar rootballs so the lowermost roots of these rootballs can be planted exceptionally deep.

The sleeve containers are constructed from 34-inch sections cut from rolls of extruded 6-mil, 11-inch layflat polyethylene tubing, available from Gemini Plastic Enterprises, Inc., 3574 Fruitland Ave., Maywood, California 90270. Lampblack and another compound included in the formulation inhibits degrada'tion of the polyethylene by ultra-violet radiation. One end of each 34-in. section is heat-hemmed to form a reinforced top and the other end is heat-seamed to form the bottom. Then, using a paper punch, drainage holes are punched into the bottom. A 6-in.-wide Futura Portable Poly Heat Sealer, available from Packaging Aids Corporation, 469 Bryant St., P. O. Box 77203, San Francisco, California 94107, has been used to heat the polyethylene in fabricating the containers.

Growth of tree roots to the full depth of the sleeve container, an initial uncertainty, was confirmed in the first year with the successful production of European hackberry and Chisos cherry (*Prunus serotina* ssp. *virens*), starting with seedling liners, age 2 years. After transplanting the liners into the sleeve containers, the containers are tied upright to a 2-foot-high wooden frame, made by nailing a 1 × 6 in. board onto 2 × 2 in. end stakes, driven securely into the ground. Four of these frames are each spaced 1 foot apart in 20-foot beds.

These and other kinds of trees grown in the sleeve containers and in standard-depth containers are now being tested under field conditions to determine any differences in root/shoot development. Treatment effects will be determined by measuring the cross-sectional root area of each tree, after Lindgren and Orlander (8), and possibly the dry weight of roots within a 1-foot-deep zone around each tree.

DISCUSSION

Trees that may be specially produced in the future to be compatible with sidewalks obviously would be targeted for a particular market, as, for example, municipalities, for planting along their streets. Their cost of production might be substantially more than for conventionally produced trees. A price differential for them compared with trees produced conventionally would have to be justified by improved tree performance as reflected in reduced long-term maintenance cost, particularly less sidewalk damage.

The person who expressed a passion for trees because "they give shade and are pretty" summed up the two basic benefits of urban trees. Discovering management strategies for throttling sidewalk damage by trees, a major and possibly unnecessary cost of their benefits, is the ultimate objective of these investigations. The nursery industry, at the front end of the "delivery system" which links producer with consumer, is a logical implementer of various products or practices which may be found desirable by these investigations.

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SEED COLLECTION AND CLEANING

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Seed collection and cleaning is an aspect of the nursery trade that is not taught in any college, university, or trade school. It is a skill acquired through apprenticeship or trial and error. Involved in the collection and distribution of seeds for 14 years, I have acquired some practical expertise.

Growers depend upon the seedsman to be a reliable and consistent source for seeds and information. Ability to meet grower needs without fault is our reputation.

Collection Sources. Much of the parent stock for regional outdoor ornamentals is available locally. Locations may be fields, nurseries, parks, schools, street plantings, or residences. Best times for locating plant material are often when the plant is highly conspicuous in bloom. Good record keeping and keen observation enable you to catalog an area on file cards and maps. A hand tape recorder allows hands-free data collection while traveling.

Habitat. Seed source should be appropriate for ultimate growing conditions. Collection locality should conform to the final growing habitat. Seedlings introduced into localities from outside their parental climate may lack adequate vigor and form.

Collection sites for cross-pollinating species must be isolated to avoid unwanted hybridization. Good examples are *Agapanthus* and *Eucalyptus*.

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Access. Permission should be obtained prior to collecting from private and public sources. On public grounds, by approaching the appropriate controlling agency having general liability insurance at hand, permission to collect is much more likely to be given. A minimum of $300,000 coverage is required, with some cities requesting up to one million dollars in coverage. Conditions of collection are that the plant shall not be damaged, its natural beauty impaired, all debris be properly disposed of, and the site be left clean.

When approaching a private source for collection privileges, you have the unique opportunity to serve as a trade liaison. I am asked for care and maintenance information for gardening problems. The homeowner is honored that their tree or shrub may supply the seed for countless progeny.

For some rare, valuable, or prolific seed stands it may be appropriate to offer a gratuity. A gratuity may endear you in the homeowner's eyes and can lead to annual collection privileges.

Preharvest. An early assessment of crop potential is important for major collections. By ascertaining crop status you can schedule collection and insure adequate supply. A nursery grower appreciates early notification of crop failure. With lead time, propagators may seek sources or propagate by other means.

Timing. Best collections are based upon concise timing. Experience within the southern and central California region show that collections can be pinpointed to within several weeks of a norm. Variation in seed ripening may be a result of weather conditions during the weeks prior to seed collection, or early or late flowering.

Determining maturity requires familiarity with the plant. Immature fruit or "green seed" is avoided. The accepted rule is, "the more mature a seed is, the greater its vigor upon germination". Fruit color, texture, and physical condition of the fruit are clues to adequate maturation. An essential cut-test made prior to all collections will verify previous conclusions, or disclose unforeseen problems. With the cut-test, look for fully developed embryos or embryos surrounded by an endosperm of uniform creamy color with a smooth pliable texture. Avoid hollow, miscolored, deformed and insect-infested seeds and fruit.

Harvesting Equipment. Ladders, telescoping poles and pruners, cone hooks, mauls, and hand implements are essential. Hardware cloth screen in 1/8, 1/4, 3/8, 1/2, 3/4 in. size is used. Trays, barrels, burlap and poly-woven sacks, tarps of canvas or economical 6 mil black U. V. resistant polyethylene, and safety equipment (climbing harness ropes, street cones, particle masks, hard hats) are the basic requirements.

Techniques for collection and cleaning vary according to three recognized fruit types (1).

Dry Fruits (I). Comprising the majority of seed formations within woody ornamentals, dry fruits are collected prior to seed dispersal. The seed bearing structure or fruit is removed whole from the plant when slightly immature. The fruit is allowed to afterripen prior to seed extraction. Fruit, branchlets, or complete branches are cut to begin the collection. Good pruning ethics are required. After ripening is accomplished by spreading plant material upon tarps in shallow layers to dry in the sun. As the fruit dries, the seeds are released from the enclosing structure. The collection must be frequently pitched and rotated to encourage uniform ripening and to discourage the occurrence of mold and fungi development because of inadequate air circulation. Examples include cones, *Cedrus, Pinus;* pods, *Brachychiton, Eucalyptus, Grevillea, Jacaranda, Wisteria;* umbels, *Agapanthus;* follicles, *Magnolia*.

Non-Dehiscent Fruits (II). Seeds covered with an adhering fruit or outgrowth are the second group. Mass collections require that fruit be fully mature with dry calm weather a key to a good collection. Fruit is hand-picked, flailed, or shaken upon tarps. Because seeds are light and often depend upon wind for dispersal, windy conditions make collection unfeasible. Examples are samaras, *Acer, Fraxinus, Liriodendron;* nuts, *Pistacia, Quercus.*

Fleshy Fruits (III). Most readily identifiable, the fleshy fruits are seeds surrounded by fleshy pulp or skin. Ripe fruit is hand-picked, knocked, or shaken upon tarps. Debris and leaves are blown from the collection. Fruit should be promptly processed. Heat buildup and fermentation may damage the enclosed seed. This group comprises berries, *Asparagus, Eugenia, Mahonia, Nandina;* drupes, pomes, aggregate fruits; and multiple fruits, *Morus*.

Cleaning facilities. A shop need not be extravagant. Cleaning areas include a drying location with good southern exposure sufficiently large to avoid cross-contamination between collections. Indoors a fanning area to air-blow collections, a wash area for wet-processed seed, a machine cleaning area, and a finish cleaning section are required.

Good hygenic practices are essential. Trays, screens, barrels and implements need to be clean and sanitized. A bleach wash (1:10) is safe, economical, and effective.

Dry Cleaning. Seed types I and II are predominantly cleaned dry. Dry material releases dust and debris in processing. Adequate ventilation and respiratory protection is imperative. Sensitive people with respiratory problems should avoid this process. Because the cumulative effects of these dusts are unknown, all persons should exercise caution. Irritants are found in *Agapanthus, Brachychiton, Cortaderia, Fremontodendron, Pennisetum, Platanus,* and *Wisteria*.

Following sun-drying the collection is threshed, releasing the seeds from the fruit. Hand threshing requires rubbing the fruit through wire screens, beating the seed capsules in trays, flailing with poles upon tarps, or pounding in sacks. Seed pods which do not respond to hand threshing and are durable may be machine-processed. Machine threshing is accomplished primarily with a hammermill, although lawnmowers and yard vacuums have proved effective. Attention must be paid to both motor speed and material volume. With too fast an engine speed, seeds become chipped, cracked, or broken; too slow and the process is unproductive. Generally, lower speeds and high volumes are most productive. The key is experience and patience. Commonly used machine-threshed seeds include: *Albizia, Carob, Cercis,* and *Cistus.*

Threshed seeds may often be finished cleaned by passing the material through an air flow produced by a multispeed fan. Low speed removes dirt, leaves, and dust. High speed removes sticks, pods, and hollow, light seeds. Heavy sound seeds fall directly below the discharge into trays. Finish cleaning is hand picking sticks, rocks, and miscolored seeds.

Air separator machines process threshed seed, producing a clean product requiring little finishing. Threshed material is passed over a scapling screen which removes large debris and sticks. Seed and smaller material passes over additional screens and an air current, removing small particles, dirt, dust, and off-sized seeds, leaving a uniform graded product. Finished seeds may require hand picking to upgrade quality. Operation requires expertise in determining screen shape and size, agitation rate, and material flow. Air separators range in price, capacity, and size, from lab models to grain processors. Hance and Clipper are two popular manufacturers. My preference is the Hance Vac-A-Way, model 3.

Wet Cleaning. Type III seeds are cleaned with water to release the encased seed from the surrounding fruit and pulp. After fanning, fruit is hand rubbed through wire screens or rubber-booted in metal barrels. Maceration is monitored to avoid splitting or crushing fragile seeds such as *Eugenia, Eriobotrya, Ginkgo, Laurus,* and *Raphiolepis.*

Hard-coated seeds are processed through a Dybvig separator, manufactured by Bouldin-Lawson Company. A revolving plate impels fruit within a metal container against a stationary plate, macerating the entire mass. The bottom revolving plate is adjusted to allow pulp and added water to flow out a discharge chute leaving behind the larger, cleaned seed. Seeds are discharged via a sliding side door when the majority of pulp is flushed out. With this method, some seeds, while exhibiting no visible external damage, may have been internally damaged. These bruised seeds may expire in storage, show poor germination and vigor, or exhibit abnormal growth. Numerous palms, *Arbutus, Celtis, Cornus, Photinia,* and *Prunus* may be machined-cleaned.

Floation. Sound seeds are separated from the pulped fruit mass through floation. Heavy sound seeds sink and settle in water barrels. Pulp will float or settle above the seeds, and is dipped or poured off. Floatation and strong agitation is continued until water flows clean and clear. Seeds are poured off upon drying screens leaving behind any rocks, sand or dirt, which settled to the bottom. A high pressure water spray completes the process by flushing away any remaining pulp.

Drying. Most wet-processed seeds must be dried of surface and excess moisture to facilitate transport and handling prior to fresh sowing. Sun drying in shallow layers removes surface moisture quickly. Dark-colored seeds dry quickly and require frequent stirring. *Aralia, Eriobotrya, Eugenia, Laurus,* and *Pistacia* should be removed from direct sun following surface drying to avoid cracking and dehiscence of the seed coat. Surface moisture should be dried promptly from *Cordyline* and white oaks because germination occurs readily under warm moist conditions. Safe storage requires seed moisture be sufficiently low to prevent germination, impair heat buildup, retard fungi growth, and restrict insect growth and reproduction.

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SOAKING SEEDS FOR IMPROVED GERMINATION

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High seed germination, if irregular, is no longer acceptable in commercial mechanized production. Seedsmen and propagators are challenged by the advent of "plug" and mechanized production systems to produce uniform seed germination at all times of the year. The single most important step a grower can take for uniform germination, after breaking dormancy, is to imbibe the seeds with water prior to sowing in soil.

The seedsperson must do his part by,

A) harvesting mature seeds from plants which will produce uniform seedlings,

B) processing the seed for long storage and easy sowing, without damaging the seed, and

C) delivering the seed with good vitality at the time needed by the propagator (2, 7, 10). Many germination problems are the result of improper seed handling.

The importance of harvesting mature seed cannot be overstated. After a seed pod or fruit has reached its maximum fresh weight there are still many changes taking place: (3, 5, 6, 7).

A) carbohydrate reserves are produced from sugars,

B) proteins and fats are stored (especially late in seed maturation),

C) nutrients are translocated from the plant to developing seeds. and,

D) three major hormonal changes occur: gibberellic acid is . . . "sequestered in an inactive form" (3), auxins accumulate in the nutritive tissue, and cytokinins are drastically reduced. Fruit and pods may appear mature to the layman but, in fact, the seed is still undergoing extensive maturation which is critical for optimum vitality.

The most important step is to initiate imbibition of the seed before the seed is sown in the soil medium. Planting seeds in the soil before imbibition results in sporadic germination . . . "by the impedance of the soil matrix due chiefly to surface and collodial forces and the degree of contact of the seed with the soil moisture" (3) which prevents seeds from imbibing water and subsequently germinating. This is documented by Pollock's work (9) where better germination occurred with higher initial seed moisture at the time of planting. It is stated by Bewley and Black (3) that . . . "the distance over which water flows to a seed through the soil often does not exceed 10mm irrespective of the soil water content". It should also be noted that this does not take into account the degree of contact between the soil holding the moisture, and the dry seed. Furthermore, late germinating seeds often die due to the changing water and environmental requirements of the seedling which have already emerged.

"Water is essential for the rehydration of seed as the initial step toward germination" (3). The uptake of water as described by Bewley and Black has a triphasic pattern: beginning with rapid imbibition of a resting seed, then a period of time where very little water uptake occurs but with increasing cellular activity and thirdly, rapid imbibition as visible germination begins. For some seeds then it is easy to soak them (preferably with distilled water) prior to sowing until the initial phase of imbibition is completed; many kinds of ornamental seed, however, have numerous barriers which prevent imbibition of water. These barriers cause different types of dormancy which are summarized by Nikolaeva (7). Dormancy has usually been overcome by use of trial and error techniques. Atwater (1) groups herbaceous ornamental plant into eight divisions according to the morphological structure of their seed. This can be used as starting guide for recommended seed treatment on herbaceous ornamentals. Atwater also lists many individual treatments for some species in each group. Some of these groupings may be applied to the woody ornamentals as well.

It is also important to maintain a perspective of the possible effects the native environment has on individual species, which includes understanding where the seed comes from and what occurs naturally for good germination (4). For example, soaking most mucilaginous seeds like Heteromeles arbutifolia or Iberis amara is counterproductive as mucilage . . . will spread around the seed and act as a pathway for the water (3); however, this group usually has more problems with gas uptake due to the mucilage (1, 4).

It is important not to oversoak seed either as some problems, such as rapid alcohol fermentation and gradual depletion of seed reserves and possible oxygen deficiency occur (8), all of which cause damage to the seed. Seed which has been "primed" by the seedsman has already received the initial imbibition necessary to start germination so it is not necessary to soak them; however, it is important to sow "primed" seed immediately.

Other considerations while imbibing include seed treated with fungicides or insecticides in the resting stage. These should be rinsed off prior to promoting imbibition as the chemicals may damage the seed during the first phase of imbibition (4). It is important not to add fungicides to the water during the initial imbibition but at the end of imbibition, or after the seed has been planted. For easy handling, surface air dry the seed lightly and sow seed immediately. Many types of mechanical machines are not able to accommodate this without overdrying the imbibed seed or damaging it. A general guide for time of seed soaking, using Atwater's classification scheme (and palms which are not included in her analysis) are as follows:

I. Endospermic seeds

A. Basal rudimentary embryo

ARALIACEAE. Soak 4–12 hours depending on size, age, and dryness of seed. Exception *Cussonia spicata,* maximum of 4 hours as it is from an arid climate and will be damaged.

B. Axillary linear embryo

PRIMULACEAE. Soak 6–24 hours again depending on age and dryness of seed. Small seeds such as *Hypericum calycinum* soaking is difficult as well as unnecessary as they are so small.

C. Axillary miniature embryo

SOLANACEAE. Soak 2–6 hours, no soak for CRASSULACEAE and BEGONIACEAE because the seeds are small.

D. Peripheral linear embryo

AMARANTHACEAE. No soaking required of *Celosia argentea*—small seeds.

II. Non-endospermic seeds

A. Hard seed coat limiting water entry

LEGUMINOSAE and ANACARDIACEAE. Soak 4–12 hours.

B. Thin seed coat with mucilaginous layer

No soaking required.

C. Woody seed coats with inner semipermeable layer.

POLIMONIACEAE. Soak 4 hours *Phlox drummondii;* smaller seed in this group should not be soaked. BALSAMINACEAE, *Impatiens* spp.

D. Fibrous seed coats with separate semi-permeable membrous layer.

COMPOSITAE. Soak 4 hours, seed will float so use a screen to press into water. (1, 4)

For the family PALMAE. Soak seeds for 24 hours; those with thick seed coats can soak longer (100 hours while changing the water often), or the seed coat must be sacrificed to allow imbibition. It is very important that palm seed be fully mature when harvested and, on most palm seed, the surrounding fruit should be removed so that the decaying fruit does not damage the seed. (4)

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PHIL BARKER: *Question for Eric Anderson. In soaking your* seeds to improve germination, just how long do you soak them?

ERIC ANDERSON: Most seeds we handle are soaked from two to 48 hours, although some kinds with very hard seed coats require from 3 to 5 days, with the water changed each day. Size of seeds and where they come from can make a difference. Very small seeds, as eucalyptus, primulas, and begonias require no soaking due to their small surface and easy absorption of moisture.

RON KADISH: In germinating seeds, I weigh the seeds before I soak them, then I start to weigh them as they are being soaked. If they gain 50% or more in weight, I find they will germinate; if they gain only 10 or 20%, I find they will not germinate.

Another interesting aspect of working with seeds; once I was collecting some *Euphorbia* seeds and had inadvertently rubbed my eyes. The next morning my eyes were swollen shut. I was sensitive to this plant, so one must be careful in working with certain toxic plant material.

PEST MANAGEMENT IN MONROVIA'S PROPAGATION DEPARTMENT

GARY PHIPPS

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18331 East Foothill Boulevard
Azusa, California 91702

Monrovia Nursery Company has a reputation of consistently producing large quantities of high quality plants. We have no secret cures nor magic potions. We do, however, approach our pest problems in a very logical, practical, and methodical manner.

Some nurserymen in California may think that pest problems cannot be managed because of the nature of their business and with pesticide regulations being what they are in California today. We have learned, however, that with time and patience, a solution can always be found. Consider the following facts about Monrovia Nursery:

(1) We do not use any restricted pesticides, except for methyl bromide.

(2) We do not use any pesticide with the word "Danger" on the label, except for methyl bromide.

(3) We do not use any pesticides that have an established reentry interval other than "stay out of treated areas until the spray has dried."

(4) We do not use pesticides that produce strong odors in the field.

(5) We border an elementary school and sixty-five private homes.

(6) We do not use biological controls because our customers will not accept beneficial insects on their plants and we cannot allow a pest population to exist to support the beneficial organisms.

(7) We will not accept any plant damage either from plant pests or from pesticides.

(8) We have 800 employees so hand labor is intensive and ever present (200 employees work in propagation).

(9) We market a portion of our crop every day and must keep our crop pest-free at all times if possible.

(10) We market our plants throughout the United States and in several foreign countries.

(11) Our goal is to produce safely and economically plants that are pest-free and damage-free.

Let us now begin by analyzing our situation, our methods of operation, our kinds of pest problems and our control for these problems.

Monrovia Nursery Company in Azusa, California, consists of about 400 acres of woody ornamentals ranging from liners to 14 gal. containers. We currently grow about 1000 cultivars that are shipped primarily in the spring of each year.

Our propagation department consists of 25 acres: 8 acres are under shade cloth, 3 acres are in glass houses, 2 acres are in outdoor mist and 12 acres are in full sun. Our propagation department produces 21 million liners each year. Our plants are propagated from seeds, cuttings, tissue culture, air layering, and grafting.

We exercise many sanitation practices to decrease our pest problems. All seed flats are steam pasteurized at 140°F for 30 minutes. All of our soil mixes are fumigated for 24 to 36 hours with methyl bromide to rid the mixes of viable weed seeds and other harmful organisms. The plastic bags we use to store cuttings are either new or washed thoroughly with a chlorine solution. Cuttings are dipped in 15ppm chlorine to clean them and then are dipped in a 200ppm Physan solution. Grafting knives, clippers, and shears are all dipped frequently in Physan and/or isoprophyl alcohol. Steam is used to clean surfaces in greenhouses. Various copper compounds are used to sanitize benches, floors, etc. Stock plants are inspected regularly for any plant pests and are treated accordingly. The list of preventative practices at Monrovia can go on and on.

When pesticides are applied in our propagation department different methods are utilized depending on the particular pest and chemical involved. Much of the time hand-carried spray guns are used. These usually provide us with the most precise application. Mist blowers are used at Monrovia because they can provide very rapid pesticide applications. Granular pesticides are applied by seeder/spreaders that scatter the particles over the plants. Hand compression sprayers are used to apply post-emergence herbicides to weeds growing on the ground. These provide very low pressures needed to insure there will be no herbicide drift to the ornamentals. Some pesticides are applied as soil drenches by using a series of nozzles joined with plastic pipe. In this way, we can apply products such as Subdue 2E fungicide for the control of water molds.

We have many different pest problems in propagation. These include fungal and bacterial diseases, insects, mites, rodents, and mollusks. Let us now examine some of these in more detail.

One of our never ending foliar diseases is loquat scab on *Eriobotrya japonica* caused by the fungus *Spilocaea pyracanthae*. This disease is typical of many of our foliar diseases in that it probably would not occur if we spaced our plants properly and did not practice overhead irrigation. We make the situation worse by irrigating at night. The disease is favored under these cultural methods and thus becomes a pest problem. We currently use fungicides such as Daconil or Dithane M-45 to combat this pathogen.

The fungal disease I am asked about most frequently by retail nurserymen is a leaf spot on *Raphiolepis indica* caused by *Ento-*

mosporium maculatum. This pathogen causes numerous small round spots on the leaves which will usually result in severe defoliation. This disease appears in our cool, wet winters and we apply alternating foliar sprays of Daconil and Benlate fungicides every 10 to 14 days with excellent control.

Another serious fungal disease we see every year is a leaf spot on *Pittosporum tobira* caused by *Alternaria tenuissima*. This fungus causes small necrotic lesions with yellow holes to develop. Once this disease is established, it is very difficult to control as are many plant diseases. We generally use a broad spectrum fungicide for control such as Benlate or Dithane M-45 as a foliar spray. It is interesting to note that *Alternaria* fungi are found almost everywhere and yet, this is the only plant we grow that is actively infected by the pathogen as the organism is not usually a primary pathogen.

The fungus *Botrytis cinerea* known as common gray mold, is generally considered to be a serious disease problem in propagation areas. We seldom have a serious problem with this pathogen, probably because we have a preventative program in force wherein we apply foliar sprays of Chipco 26019, Dithane M-45, or Benlate in combination with streptomycin in certain areas of our propagation department that would be likely to have assorted disease organisms.

Another fungal disease we see every year is scab on our hardy orange-berried firethorns (*Pyracantha*) caused by *Spilocaea pyracanthae*. Instead of the characteristic blackish decay of berry clusters, we usually see the disease as a black spot or blotch on the underside of the leaves. This disease occurs primarily in our rainy season and can cause defoliation of the host. However, the plants quickly put out a flush of new growth and seem to "outgrow" the disease. We also make foliar applications of Benlate or a fixed copper fungicide. This disease is caused by the same pathogen that causes loquat scab.

Everyone has probably seen powdery mildew at one time or another. We are fortunate at Monrovia in that this fungus is not a serious problem for us. Several different pathogens can cause this disease and are rather host specific. We have had good success using Bayleton fungicide as a foliar spray but because its label is a bit restrictive, we sometimes use Benlate.

Of all the various fungal diseases, probably the most costly are the crown and root-rot pathogens. For the water molds, *Phytophthora* spp. and *Pythium* spp., we have a rather extensive preventative program of applying every 3 months a soil drench of Subdue 2E or a granular application of Subdue 5G to a group of selected host plants. If other pathogens, such as *Fusarium* spp. are suspected, we add Benlate fungicide to the soil drench.

We also have problems with some bacterial diseases such as crown gall caused by *Agrobacterium tumefaciens*. This pathogen frequently attacks several *Euonymus* cultivars necessitating the disposal of the infected plants. We have tried many different ways to control this pathogen, but we obviously have not found a good practical control to date. No doubt our sanitation practices aid greatly in reducing the spread of this pathogen.

All but one of our deciduous *Magnolia* cultivars are subject to a bacterial leaf spot caused by *Pseudomonas syringae* and *Pseudomonas cichorii.* These diseases manifest themselves as black angular leaf spots which can be very numerous. These diseases have been shown to develop more rapidly in areas of high humidity and can be quite serious to our customers in the eastern parts of the United States. Chemical controls for bacterial diseases have not been very successful, but we continue trying with streptomycin or fixed copper fungicides. It is interesting to note that these bacteria tend to resist crossing major veins in a leaf. Therefore, infected monocots will show striping of the leaves as the bacterial infection follows the longitudinal veins.

We have learned that sometimes *Pseudomonas* bacteria will cause a "shot-hole" effect on some plants such as *Prunus laurocerasus.* In these instances, the plants do not seem to suffer except in appearance. The leaf tissue dies and literally drops out onto the soil surface below. For some unknown reason, the disease symptoms are reduced when the plants are grown under shade cloth.

Our *Hedera helix* cultivars are often attacked by the bacterium, *Xanthomonas hederae,* causing a black spotting of the foliage. Under our growing conditions we have found chemical controls to be inadequate. This disease is favored by our practice of overhead irrigation at night and inadequate plant spacing.

Our plants are also attacked by numerous species of aphids. We have found our aphid species to be easily controlled with foliar sprays of Orthene, Dursban, or Mavrik insecticides.

Mealybugs and scale insects sometimes infest our plants. Our best approach to controlling these pests has probably been to keep our parent stock free of these insect pests. In the cool winter months, we apply a superior oil to our parent stock which will control overwintering mealybugs and scale insects. In the warmer months when these pests are found we make foliar applications of Dursban. In the past, we had good control with Diazinon, but we switched over to Dursban because it would control two additional serious insect pests and did not cause defoliation of *Stephanotis floribunda.*

Of all the lepidopterous pests we have, the beet armyworm, *Spodoptera exigua,* has proven to be the most serious. This pest has an almost limitless host range and has proven to be capable of infesting the entire nursery almost overnight. Damage potential from this pest is very great. We no longer use *Bacillus thuringiensis* to control our lepidopterous pests because we found it would not control the beet armyworm. We have had great success using foliar sprays of Orthene or Dursban insecticides. Dursban offers the advantage of producing a very quick "knock down" of the pest.

Whiteflies can sometimes be quite numerous on plants such as *Lantana* spp., *Abutilon* spp., and *Philadelphus* spp. I have never seen any damage from whiteflies but our customers will complain if their plants are infested. We are currently using a low rate of Mavrik Aquaflow with outstanding results.

Thrips are an interesting plant pest because the plant damage from their feeding is often evident even though a single thrip cannot be found. Thrips like to feed within the growing bud of a plant, and are seldom exposed. Many times we will see thrips on the flowers of ornamentals but see no sign of any damage. We usually will see thrips damage on plants such as *Acer palmatum* and *Gardenia jasminoides* during the warm summer months. The damage usually appears as a stippling of the foliage or severe distortion of the new growth. We have found the insecticide Dursban to be quite effective in controlling these pests. We currently are adding Pyrenone insecticide at a low rate to serve as an "exciter" to force the thrips out of the buds so that they might become more exposed to the Dursban. This appears to help but our conclusions are not final at this time.

Spider mites cause us many problems all over our nursery. Their host range is very broad and they are seldom seen by our employees. They require very good coverage of the plant by an effective miticide if chemical control is to be successful. We currently use Morestan, Mavrik, or Avid with good results. We use very little Avid since its California label is very restrictive.

Mollusks sometimes damage our plants in propagation and elsewhere. Our primary mollusks are various species of slugs. They are widespread over the nursery, but cause damage to few of our plants. Therefore, we restrict our control efforts to those plants that are likely to sustain damage from the slugs. We have found the molluskicide called Deadline Bullets to be very efficacious against our slugs. This material is applied through a seeder/spreader over the tops of the plants.

Rodents can cause us losses either by eating the seeds we plant or by girdling stems and trunks of our plants. We have tried different kinds of poison baits with varying results. With any bait, good results depend primarily on the bait being accepted by the rodent. We have found the rodenticide called Contrac Paraffinized Cake to be very readily accepted by mice and rats and to be extremely effective.

We at Monrovia know that first and foremost, we must go out and look at, or scout, our plants for pest problems. We scout our fields every thirty days. Our propagation department should be scouted more often. We utilize many preventative programs and each one of them is based on our findings from field scouting. Currently, we do not rely on pheromore traps or yellow sticky cards for pest detection. We must scout all areas of our nursery for all plant pests continuously since we grow many different kinds of plants and we feel these "state of the art" methods would not serve us well.

Pest management in Monrovia's propagation department is a varied and complex part of our business. Prevention is the real key to our success and is achieved by sanitation, field scouting, and preventative programs.

A COMPARISON OF THE PROPERTIES OF SLOW-RELEASE FERTILIZERS IN CONTAINER PLANT PRODUCTION

GEORGE SCHMITZ

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The subject to be presented today has been very effectively summarized in two recent publications: Wise Fertilizer Selection and Application Enhance Container Success (1) and the very recent book, Fertilizer Technology and Use (2).

Slow-release fertilizers can be placed in two categories: slowly degraded, and coated.

Some fertilizers that degrade slowly release nutrients gradually because the fertilizer formulation has low solubility; IBDU is an example. Others, such as urea-formaldehyde, degrade slowly because they require microbial activity to release the nutrients. Most fertilizers in the slowly degraded group are formulated to last effectively for 8 to 12 weeks and are usually surfaced-applied.

The other group of slow-release fertilizers, coated materials, contains soluble fertilizers encapsulated with either sulfur or resin. Typically, they are formulated to release nutrients for 3 to 12 months and vary in type, quality, longevity, and cost.

Sulfur-coated fertilizers contain soluble components coated with sulfur, a soft wax sealant, and a microbicide. The sealant slows the transfer of water vapor to the soluble components, thus delaying nutrient release. The microbicide slows the rate of sealant each one of them is based on our findings from field scouting. Currently, we do not rely on pheromore traps or yellow sticky cards for pest detection. We must scout all areas of our nursery for all plant pests continuously since we grow many different kinds of plants and we feel these "state of the art" methods would not serve us well.

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Sulfur-coated fertilizers contain soluble components coated with sulfur, a soft wax sealant, and a microbicide. The sealant slows the transfer of water vapor to the soluble components, thus delaying nutrient release. The microbicide slows the rate of sealant decomposition. Decomposition and release rates are influenced by the thickness and uniformity of the sulfur coating and the rate of microbial activity.

Resin-coated products compose the second type of coated fertilizers. With this type, a plastic polymer coating encapsulates the soluble fertilizers. When the medium is wet, moisture diffuses into the prill (fertilizer pellet) and dissolves the fertilizers, which slowly diffuse into the growth medium. In a moist environment, the release rate is controlled by coating thickness, coating type, and ambient temperature.

Coated fertilizers offer the greatest flexibility in nutrient longevity and application methods. Ideally, a slow-release fertilizer needs to be applied only once, and nutrients will be metered throughout the production cycle. While this objective can be successfully achieved with many nursery crops, the development of such a fertilizer program should be based on a thorough knowledge of crop scheduling and available fertilizer products.

Table 1 outlines various characteristics of certain controlled-release fertilizers.

Table 1. Characteristics of some common controlled-release fertilizers*

Control method	Material	Availability of N increase with:	Period of effectiveness
Biological degradation	Animal manures Sewage sludge Hoof and horn meal	Temperature, moisture, pH near 7	2 to 4 weeks 2 to 4 months
Low solubility and biodegradation	Ureaform	Temperature, moisture, pH near 7	Variable, averaging 0.4% per day
Coated soluble materials	Osmocote SCU	Temperature Temperature and moisture	Variable, 3 to 9 mo. Variable, approximately 1% per day
Low solubility	IBDU	Exposed surface, soil moisture and acidity to pH 4	3% per week for 1 mm particles
	MagAmp	Moisture and acidity	100 days for coarse granules
Nitrification inhibitor	Nitropyrin	Soil organic matter and temperature	2 to 10 weeks
Urease inhibitor	None recommended	Temperature and other factors	———

*Adapted from Maynard and Lorenz (1979) and Hauck and Koshino (1971).

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THE EFFECT OF IBA AND/OR NAA AND CUTTING WOOD SELECTION ON THE ROOTING OF *RHAPHIOLEPIS INDICA* 'JACK EVANS'

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Abstract. Solutions of IBA (0, 1000, 5000 and 9000 ppm), NAA (0, 1000 and 2000 ppm) and all possible IBA + NAA combinations were tested for effectiveness in rooting cuttings taken from the upper and lower portions of semi-hardened shoots of *Rhaphiolepis indica* 'Jack Evans.' Combinations produced rooting which was greater than that produced using IBA or NAA alone. With minimal compound use, 5000 + 2000 and 9000 + 1000 (IBA ppm + NAA ppm) yielded the greatest percentages of transplantable cuttings (67 to 68%). Cuttings prepared from the upper and lower portions of shoots responded similarly to the range of solutions tested, with cuttings from lower portions rooting only slightly better than those from upper portions.

INTRODUCTION

Rhaphiolepis indica 'Jack Evans' is considered to be a moderately difficult plant to propagate. In nursery production, rooting percentages range from 40 to 70%. Traditionally, 3-indolebutyric acid (IBA) has been used to promote rooting. But more recently, improved rooting has resulted from using IBA in combination with 1-naphthaleneacetic acid (NAA) (1).

Preliminary rooting studies on *R. i.* 'Jack Evans' were carried out to understand the effectiveness of IBA or NAA used individually. Results from these studies indicated that the effective concentration range for IBA was 6000 to 12,000 ppm while that for NAA was 1000 to 3000 ppm. It was also noted that cuttings which had been taken from the lower portions of semi-hardened shoots seemed to root better than cuttings which had been taken from the upper portions. These findings led to the present study in which solutions of IBA and NAA, alone and in combination, were tested on cuttings taken from the upper and lower portions of semi-hardened shoots of *R. i.* 'Jack Evans' to determine the following:

1. If IBA + NAA combinations more effectively root cuttings than do IBA or NAA alone.
2. If cuttings prepared from the lower portions of semi-hardened shoots root better than cuttings selected from upper portions.
3. If the same solutions can be used to root cuttings selected from both the upper and lower portions of a semi-hardened shoot.

METHODS AND MATERIALS

Twelve rooting solutions were tested on each of 2 cutting types for a total of 24 treatments. Each treatment involved 15 cuttings and was replicated 7 times.

The 12 rooting solutions (Table 1) resulted from a factorial combination of 4 IBA concentrations (0, 1000, 5000 and 9000 ppm) with 3 NAA concentrations (0, 1000 and 2000 ppm). All solutions were 50% ethanol by volume.

Table 1. Rooting solutions tested (IBA ppm + NAA ppm)

IBA	NAA	Combinations	Control
1000 + 0	0 + 1000	1000 + 1000	0 + 0
5000 + 0	0 + 2000	5000 + 1000	
9000 + 0		9000 + 1000	
		1000 + 2000	
		5000 + 2000	
		9000 + 2000	

Cuttings were made October 11, 1984 from 11 to 14 in. shoots gathered from plants grown in #4 containers. After the soft tip was discarded, the remaining semi-hardened stem provided two cuttings: one from the upper, softer, brown-maroon, finely-haired, younger portion, and another from the lower, harder, brown, finely-grained, older portion. Throughout this report these cutting types will be referred to respectively as upper and lower cuttings.

The top stem cut of an upper cutting was made approximately 1 in. below the point where the wood had begun to harden. The top stem cut of a lower cutting was made at the color transition from brown to brown-maroon. Diagonal bottom cuts for both cuttings were made 3¼ in. below top cuts. The 3 to 4 fully expanded leaves remaining after lower ones were removed by tearing made the total cutting length approximately 5 in.

Cuttings were stuck in 14 flats: 7 for lower cuttings and 7 for upper cuttings. Each flat held one replication of each of the rooting solution treatments. Within a flat, rooting treatments were organized into 12 randomized rows of 15 cuttings each with one treatment per row. This block of treatment rows was buffered on two sides by double rows of cuttings to protect against edge effects, bringing the total rows per flat to 16.

Before sticking, the basal ends of cuttings (½ to ¾ in.) were treated with the test solutions using the quick dip method (<1 second in solution). Cuttings were stuck in flats containing coarse perlite and expanded fine peat (9:1 by volume). Flats were then placed on a heated bed under intermittant mist in full sun. Root zone temperature was maintained between 68° and 73°F. Mist was applied during the day as needed, usually every 8 or 16 min. for 4 to 6 sec.

After a 40-day rooting period, cuttings were removed from the mist and 8 days later, harvested. Treatment rooting percentages were then determined for 2 categories: *transplantable cuttings* which consisted of cuttings with a minimum of 5 to 6 roots, each at least 1 in. in length, and *rooted cuttings* which consisted of all cuttings with roots (including transplantable ones).

RESULTS AND DISCUSSION

Most Effective Solutions. Three solutions, 5000 + 2000, 9000 + 1000, and 9000 + 2000, produced the highest rooting percentages for *R. i.* 'Jack Evans' (Table 2). For transplantable cuttings, these percentages ranged from 67 to 68% and for all rooted cuttings, from 85 to 91%. It should be noted that these more highly concentrated solutions gave results not statistically different from others tested. However, they were determined to be most effective since the general trend among treatments was for percentages to increase as concentrations increased (Figure 1).

Table 2. The effect of IBA and/or NAA on the rooting of *Rhaphiolepis indica* 'Jack Evans'[1].

Transplantable Cuttings		All Rooted Cuttings	
IBA + NAA(ppm)	Rooting %[2]	IBA + NAA(ppm)	Rooting %
9000 + 1000	68 a	9000 + 1000	91 a
9000 + 2000	67 a	5000 + 2000	89 ab
5000 + 2000	67 a	9000 + 2000	85 abc
0 + 2000	58 ab	0 + 2000	84 abcd
1000 + 2000	58 ab	1000 + 2000	83 abcd
5000 + 1000	53 ab	5000 + 1000	79 abcd
9000 + 0	47 ab	9000 + 0	76 abcd
0 + 1000	41 b	1000 + 1000	73 bcd
1000 + 1000	38 b	0 + 1000	70 cd
5000 + 0	36 b	5000 + 0	62 d
1000 + 0	7 c	1000 + 0	33 e
0 + 0 (control)	6 c	0 + 0 (control)	23 e

[1] 30 cuttings per treatment replicated 7 times.
[2] *Mean separation within columns by Duncan's Multiple Range Test at the 10% level* of significance.

Of the three most effective solutions, 5000 + 2000 and 9000 + 1000 produced high rooting with minimal compound use. No additional rooting resulted from using the more concentrated 9000 + 2000 solution.

Extrapolation from the data indicates that rooting percentages higher than those which occurred may be obtained with other solutions. For example, in Figure 1 with solutions containing 1000 ppm NAA, rooting may continue to increase as IBA is increased to levels higher than 9000 ppm. Likewise with solutions containing 5000 ppm IBA, rooting may continue to increase as NAA is increased to levels higher than 2000 ppm.

Effectiveness of IBA + NAA Combinations. For each IBA concentration, the combination with NAA resulted in higher rooting percentages than when IBA was used alone (Figure 1).

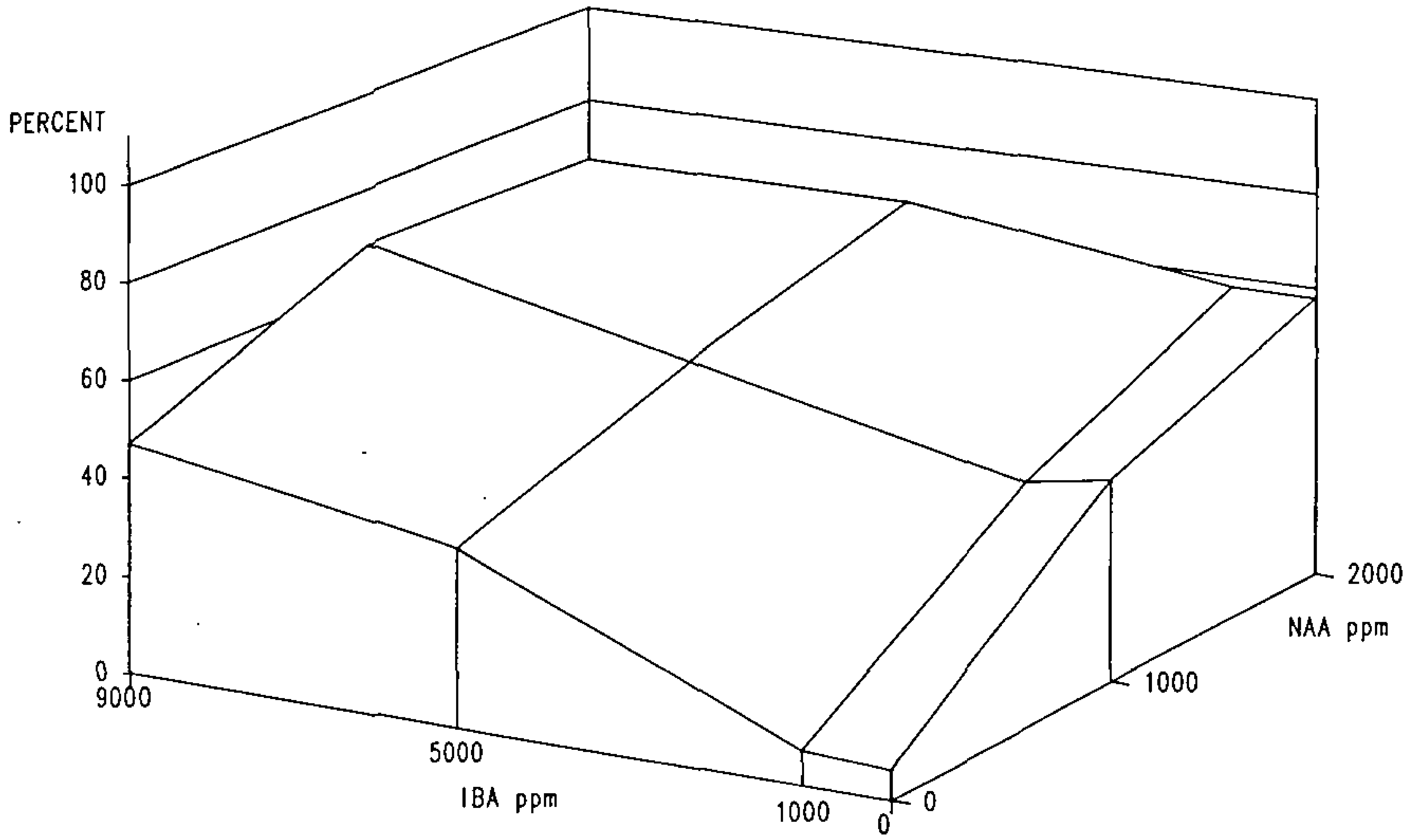

Figure 1. The effect of IBA and/or NAA on the rooting of *Rhaphiolepis indica* 'Jack Evans' (transplantable cuttings).

Likewise, for each NAA concentration, the combination with IBA (except for 1000 ppm) resulted in higher percentages than when NAA was used alone. These differences indicate that IBA + NAA combinations are generally more effective than is IBA or NAA alone.

When IBA + NAA combinations are compared at a particular rooting percentage, it is observed that the effectiveness of a particular combination lies not in any ideal IBA or NAA concentration, but in their relative concentrations. An inverse relationship between the compound concentrations of a solution may be seen when comparing the equally effective 9000 + 1000 and 5000 + 2000 combinations. For 9000 + 1000, a high concentration of IBA is effective with a low-medium concentration of NAA, but for 5000 + 2000, a lower concentration of IBA is effective with a high concentration of NAA.

Effect of Cutting Wood Selection. Lower cuttings had higher rooting percentages than did upper cuttings for the majority of rooting solutions (Table 3). When averaged for all rooting solutions, the data for transplantable cuttings indicate that 6% more lower cuttings rooted than did upper cuttings (Table 4). Likewise, for rooted cuttings, 9% more lower cuttings rooted than did upper cuttings. When analyzed, the 6% difference was not found to be significant while the 9% was. Though these results indicate that cuttings taken from the upper and lower portions of semi-hardened shoots may root differently, the difference is minor.

Table 3. The effect of IBA and/or NAA on the rooting of upper and lower cuttings of *Rhaphiolepis indica* 'Jack Evans' (transplantable cuttings)[1].

Upper Cuttings		Lower Cuttings	
IBA + NAA(ppm)	Rootings %[2]	IBA + NAA(ppm)	Rooting %
9000 + 2000	69 a	9000 + 1000	69 a
9000 + 1000	67 ab	5000 + 2000	69 a
5000 + 2000	65 ab	0 + 2000	66 a
1000 + 2000	51 ab	9000 + 2000	66 a
0 + 2000	50 ab	1000 + 2000	64 a
9000 + 0	49 ab	5000 + 1000	57 a
5000 + 1000	49 ab	0 + 1000	49 a
1000 + 1000	41 ab	9000 + 0	46 a
0 + 1000	34 ab	5000 + 0	43 a
5000 + 0	31 b	1000 + 1000	34 ab
1000 + 0	6 c	1000 + 0	9 bc
0 + 0 (control)	3 c	0 + 0 (control)	8 c

[1] 15 cuttings per treatment replicated 7 times.
[2] Mean separation within columns by Duncan's Multiple Range Test at the 10% level of significance.

Table 4. The effect of cutting position on the rooting of *Rhaphiolepis indica* 'Jack Evans'[1].

	Rooting %[2]	
Cutting Position	Transplantable Cuttings	All Rooted Cuttings
Lower	46 a	77 a
Upper	40 a	68 b

[1] 180 cuttings per treatment replicated 7 times.
[2] Mean separation within columns by Duncan's Multiple Range Test at the 10% level of significance.

Effect of Rooting Solutions on Upper and Lower Cuttings. Rooting solutions which were most and least effective for rooting upper cuttings were generally the same as those which were most and least effective for lower cuttings (Table 3). This indicates that *the recommended rooting solutions for R. i. 'Jack Evans' will be* suitable for all cuttings selected from the semi-hardened portions of shoots.

CONCLUSIONS

Combinations of IBA and NAA are more effective for rooting *Rhaphiolepis indica* 'Jack Evans' than is IBA or NAA alone. The concentrations of IBA and NAA used in equally effective combinations *may* be inversely related; a high concentration of one compound is effective with a low concentration of the other compound.

Of the solutions tested, the combinations 5000 + 2000 and 9000 + 1000 (IBA ppm + NAA ppm) are recommended because they maximize rooting percentages while minimizing compound use. For the cost-conscious propagator, 5000 + 2000 is more highly recommended since the cost of NAA is one-fifth that of IBA.

Cuttings prepared from the lower portions of semi-hardened shoots root only slightly better than those selected from upper portions. While it is important to consider wood selection during cutting preparation, the choice of the proper rooting solution can have a greater impact on the rooting of *Rhaphiolepis indica* 'Jack Evans'.

Cuttings prepared from both the upper and lower portions of a shoot have the same relative responses to rooting solutions. Thus, the recommended solutions can be used for all cuttings which are derived from the semi-hardened portions of shoots.

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1. Berry, James B. 1984. Rooting hormone formulations: a chance for advancement. *Proc. Inter. Plant Prop. Soc.* 34:486–491.

A 17-YEAR CASE HISTORY OF RESEARCH AND IMPLEMENTATION OF WATER RECYCLING ON CONTAINER NURSERY STOCK

CONRAD A. SKIMINA

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INTRODUCTION

This is a case history report on our progress in recycling irrigation runoff water over container ornamentals. In 1974, at the 15th Annual Meeting of IPPS, Western Region, I described a minor system of filtration of water for reuse. Later that year, we began more intensive research in the study of recycling water. This report describes the increase in knowledge gained since the original project was conceived, the culmination of this research, and the resulting construction of a 2.0 million gallon per day (MGD) (7571 m^3) water processing plant, and the results since we began recycling in 1979.

HISTORY

In 1971 we foresaw the need to control water pollution and to conserve water. In this respect we studied nitrogen (N) in the environment to determine ways to reduce its usage and we built a minor filtration plant with the thought of recycling both the water maximize rooting percentages while minimizing compound use. For the cost-conscious propagator, 5000 + 2000 is more highly recommended since the cost of NAA is one-fifth that of IBA.

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Cuttings prepared from both the upper and lower portions of a shoot have the same relative responses to rooting solutions. Thus, the recommended solutions can be used for all cuttings which are derived from the semi-hardened portions of shoots.

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HISTORY

In 1971 we foresaw the need to control water pollution and to conserve water. In this respect we studied nitrogen (N) in the environment to determine ways to reduce its usage and we built a minor filtration plant with the thought of recycling both the water and the nutrients. We soon found that irrigation runoff could not simply be filtered and reused. Extensive research followed to study: 1) the effects of herbicides in a recycling system, 2) the effects of water treatment chemicals on plants, 3) chlorine and chloramine phytotoxicity, 4) the effectiveness of flocculation chemicals and polymers on clarification of water, 5) disinfection of water, 6) salinity build up, 7) disposal or reuse of sludge resulting from water treatment, 8) the efficacy of sedimentation, 9) the design of systems for water collection and pumping, 10) runoff and water consumption, 11) the change in elemental constituents of the runoff and processed waters, 12) hydraulic consideration in treatment, and 13) costs of treatment.

This research provided us with a wealth of information to reinforce our decision to recycle. The culmination was the construction of a water treatment plant in 1979. It consists of 7 sedimentation pits, an equalization reservoir, upflow clarifier, filter, blending pit, and storage reservoir. The water drains from sloping land areas into open ditches which congregate and flow into sedimentation pits. The purpose of the pits is to provide a small, quiescent water basin to allow the large particles, such as sand and silt to settle out and to remove floating debris by baffling. Water, laden with colloidal matter, overflows into pump pits, where pumps deliver the water to an equalization basin. From this point the water is pumped into a treatment building where flocculation and coagulant aids are added to the water to promote flocculation of the suspended clays. The pH is adjusted to fit our parameters for least solubility of the coagulants and greatest efficacy of flocculation. Clarification follows as a consequence of settling of the flocculated clay. The water is disinfected with monochloramine and filtration proceeds through dual media filters consisting of anthracite coal and sand. After polishing the water by filtration, it is blended at a ratio of approximately 1:1 with fresh, fortified water to make up the losses due to percolation and evaporation. The finished water flows into a 1.3 million gallon (4921 m^3) reservoir for reuse (Figure 1).

RESULTS

Water conservation. Recycling results in a 50% water conservation.

Fertilizer conservation. With a constant fertilization system, a 50% saving in water translates into a 50% recycling of fertilizer nutrients also. Since the water recycling is a closed system, nutrient leachates from container media are also recycled. This provides us with a considerable amount of nitrogen, potassium, calcium, magnesium, copper, zinc, manganese, and boron, negating the need to add these to the fresh, makeup water.

A side benefit is a change in the form of N that returns with the

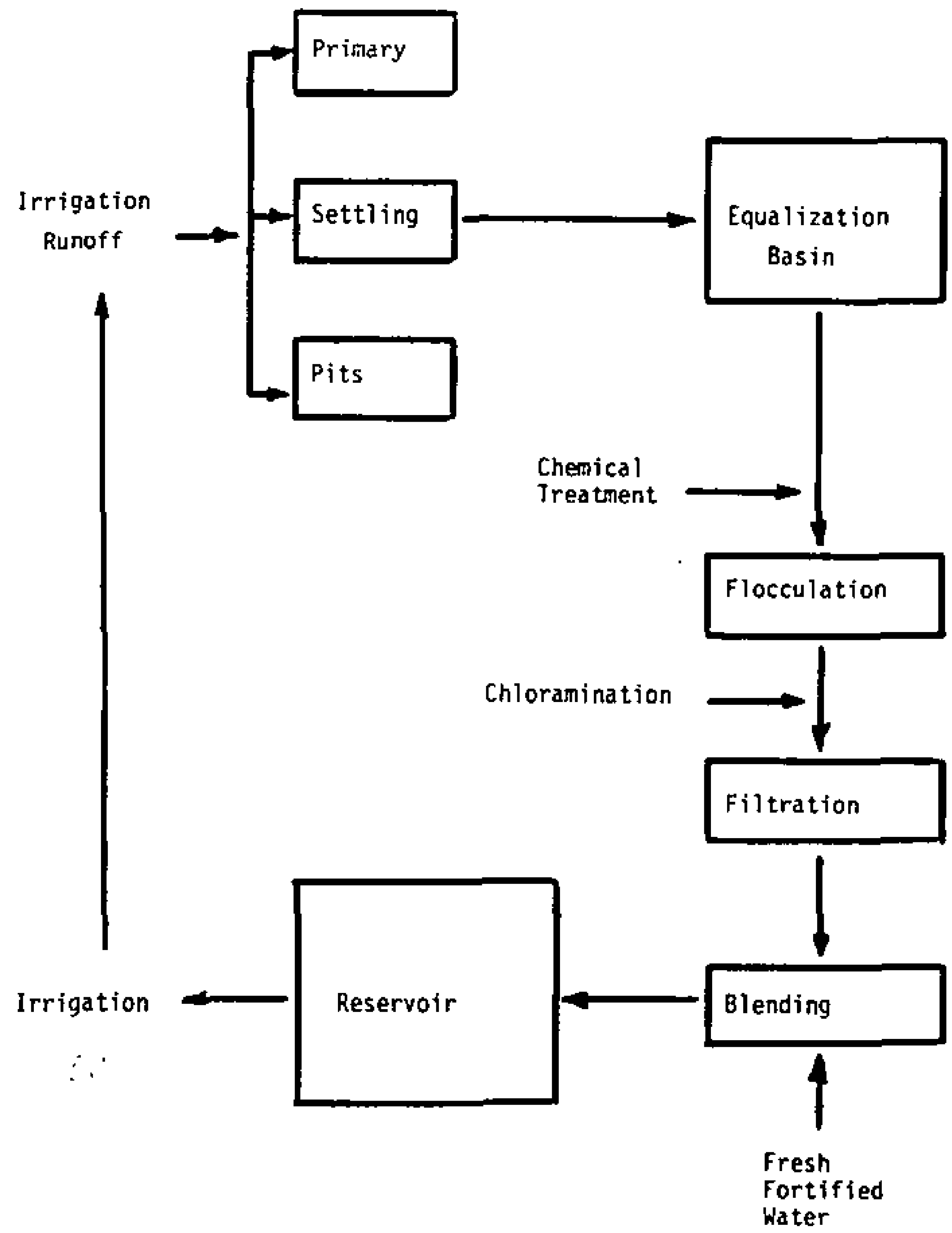

Figure 1. Schematic of water recycling and treatment.

runoff. Fresh water whould normally be fortified with ammonium nitrate, supplying 50% ammonium N and 50% nitrate N. The processed water results in a decrease in the ammonium N and an increase in the nitrate N as a consequence of nitration bacteria. Acid production in the soil is decreased, reducing the amount of corrective liming previously required to adjust the pH (Table 1).

Economics. The cost of water treatment has been determined to permit us to determine savings. It presently costs us $378 to process one million gallons (3785 m^3) (Tables 2 and 3).

Since our size permits us to obtain water treatment chemicals and fertilizers in quantity at lower costs, I calculated the costs and savings for a smaller grower, if he were to recycle. Based on lower quantity purchases, it would cost a smaller grower approximately $552 per million gallons (3785 m^3) to process water to the same degree of clarification. On the other hand, their saving in water costs and fertilizer are considerably more since they pay more for these items (Table 4). These savings do not allocate any costs of amortization of the capital expenditure.

Another added benefit we did not foresee initially was an 82% reduction in *Poa annua* seed germination. Recent chromatographic analyses of our processed water revealed we have a range of 0.002 to 0.038 mgl^{-1} of the various preemergence herbicides we use in our system. The herbicides we chose to use are based on our original studies with runoff from experimental plots treated with specific

Table 1. Percent change in constituents in processed runoff water.

Compared with fortified fresh water (blend water)	Constituent	Compared with reservoir water[z] (irrigation water)
140	H	100
−0.4	pH	−0.3
11	EC	7
−45	NH_4 N	−20
38	NO_3 N	8
0.6	Total N	−0.6
0	P	25
17	K	2
184	Ca	54
189	Mg	44
14	Fe	14
50	Cu	0
150	Zn	67
360	Mn	92
113	Na	55
3	B	−6
6	NTU[y]	−3

[z]50% processed runoff + 50% fresh fortified water
[y]Nephelometric turbidity units

Table 2. Cost to reclaim wastewater.

Agency	Source	Cost ($US) Acre-foot	10^6 gal.	1000 m^3
Los Angeles	Sewage	168	517	137
San Bernardino	Sewage	155	476	126
Monrovia Nursery	Irrigation runoff	123	378	100

Table 3. Allocation of costs of water treatment.

Item	Percent
Energy	47.8
Chemicals	38.4
Equipment maintenance	5.1
Labor	8.7
Total	100.0

herbicides. This processed water is diluted by 50% makeup water before recycling, resulting in an additional decrease in concentration of herbicides.

Water quality. Our fresh water supply is of excellent quality, being low in salinity, sodium, and boron. Even with the great amount of added nutrients, the concentration of all the elements falls into satisfactory levels for good quality water. Salinity increases on the average of 7% per cycle; however, the increase is at a decreasing rate since it is blended with lower salinity fresh, fortified water. The range of salinity may range from 0% in the winter to

Table 4. Potential savings of water and nutrients by the small grower using water recycling.

		$US per million gallons (3785 m^3)
Value of water		676^z
Value of nutrients		790^y
		1040^x
	Range	1466 to 1716
Lowest value of water and nutrients saved		1466
Estimated cost of water treatment		−552
	Net saved	914

^{z}Mean for six southern California counties
^{y}Based on small quantity purchases of 5 tons or less per primary nutrient fertilizer; chloride formula
^{x}Based on small quantity purchases of 5 tons or less; sulfate formula; assumed 200 mgl^{-1} N and 100 mgl^{-1} K

28% per cycle occasionally in the summer. The clarity of the water is very good, sometimes exceeding that of drinking water.

Chlorine gas is used as the disinfectant, immediately forming monochloramine because of the chemical nature of our water. Monochloramine is more stable to sunlight than chlorine. We maintain a residual monochloramine well below phytotoxic levels. Periodic MPN (most probable number) coliform tests and agar plate counts are made to determine efficacy of disinfection.

Plant response. Plant response was tested several times prior to recycling water. After the treatment plant was built, we conducted another, more extensive study of plant response. The study was conducted on 106 species. Plants grown under overhead irrigation with recycled water (50% processed runoff + 50% fresh, fortified water) were compared with plants grown under equal salinities of fresh, fortified, noncycled water. Visual evaluations were made on all 106 species and actual growth measurements were made on selected 31 species. Our mean growth for 106 species was 103% compared with 100% for fresh water (Table 5).

CONCLUSIONS

Water recycling appears to be a viable means of conservation of water and nutrients. Our commitment to recycling is indicated by continuing this practice in our Oregon location.

With the prospects of fresh water shortages with increasing populations, the trend is toward more water conservation throughout the United States.

VOICE: Question for Conrad Skimina. What was the total cost of your water recycling installation?

CONRAD SKIMINA: The plant cost 1.3 million dollars in

Table 5. Plant response to recylced[z] vs non-cycled water[y]

Plant	% Relative growth[x], recycled water
Actinidia chinensis	159[w]
Araucaria heterophylla	96
Arbutus unedo 'Compacta'	95
Berberis thunbergii 'Atropurpurea'	171
Brunfelsia pauciflora 'Floribunda'	85
Buxus microphylla var. *japonica*	100
Cedrus deodara	104
Cinnamomum camphora	94
Crassula argentea	120
Cryptomeria japonica 'Nana'	100
Cupressus sempervirens 'Glauca'	100
C. macrocarpa 'Donard Gold'	90
Ensete ventricosum	111
Gelsemium sempervirens	73
Hibiscus mutabilis 'Rubrus'	91
H. rosa-sinensis 'Ross Estey'	85
Juniperus chinensis 'Keteleeri'	120
J. chinensis 'Robust Green'	92
J. sabina 'Broadmoor'	100
J. scopulorum 'Pathfinder'	110
J. virginiana 'Cupressifolia'	100
Magnolia grandiflora	102
Mahonia aquifolium 'Compacta'	102
Nerium oleander 'Cherry Ripe'	95
Osmanthus heterophyllus 'Variegatus'	110
Pinus canariensis	95
P. thunbergiana	95
Platycladus orientalis 'Aureus Nanus'	84
Prunus caroliniana 'Bright N Tight'	160
Raphiolepis indica 'Enchantress'	94
Syzygium paniculatum	73

[z]50% processed runoff and 50% fresh fortified make-up water
[y]Fresh, fortified water
[x]Compared with 100% for non-cycled water
[w]Means of 14 replicates

1979. The rate of flow is 1400 gal. per min., approximately 2 million gal. per day.

VOICE: Conrad, what happens to the sludge residue left from your water treatment?

CONRAD SKIMINA: The sludge that settles out in the sedimentation pit is removed by a front end loader and hauled away to a dry land area.

VOICE: Gary, do you use spreader-sticker at all in your sprays at the nursery?

GARY PHIPPS: Yes, most of the time we do.

VOICE: Question for Bruce Lane. At what time in the year do you take your *Raphiolepis* cuttings?

BRUCE LANE: In southern California we take our cuttings from July to October, but mainly in September.

CURTIS J. ALLEY WESTERN REGION AWARD OF MERIT

Presented by Mr. Ed Kubo, President of the IPPS Western Region, at the annual banquet, Sheraton Santa Barbara Hotel.

This year the Curtis J. Alley Merit Award recipient is a person we all admire and respect because of his vision, his "young ideas," compassion, understanding, and leadership.

He is a charter member of The International Plant Propagators, Western Region, serving as President of the Western Region in 1967, and International president in 1970.

He has served on many committees, including the Finance Committee, Long Range Planning and Nomination Committee, Site Committee, Research and Scholarship Committee, Education Award Committee, and the Awards Committee.

When I was told who the recipient of this award would be, I was thrilled and honored that I was going to make this presentation. He is a man that I admire and respect, a man that showed me how to seek and share, who questioned my decisions and made me think again. He was a pioneer in the development of the U.C. system of growing plants and he is well known as the man that developed the 'Santa Anita Race Track' pansy. He has owned Union Nursery and Tropico Nursery Sales. This man is Mr. Henry Ishida.

INNOVATIONS IN AIR LAYERING

WILLIAM L. NELSON

Pacific Tree Farms
4301 Lynwood Drive
Chula Vista, California 92010

Air layering seems to be one of the least used methods of propagation. I think that this is largely due to the fact that air layers are messy, awkward, and may be dangerous to apply. Imagine standing near the top of a 16-ft. orchard ladder holding a wad of wet peat moss around a branch with one hand and wrapping it with binder twine with the other. A sudden breeze and some sweat burning your eyes may make tissue culture sound pretty good.

At our nursery, air layering has been a great help in building the inventory of many rare or slow-growing trees. Along the way we have picked up a number of ideas that have helped to make this method more effective and safe. It is used primarily in the propaga-

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At our nursery, air layering has been a great help in building the inventory of many rare or slow-growing trees. Along the way we have picked up a number of ideas that have helped to make this method more effective and safe. It is used primarily in the propagation of litchi, longan, mango, macadamia, and guava. We can produce a well developed and saleable tree in less than a year where other methods could take 2 or 3 years.

Following are refinements that have been of assistance to us:

1. To remove the bark section in the girdling process, we have found a regular pair of pliers works very well. The bark is literally torn away. When the bark is very stringy as with mango trees, it is necessary to make two circular cuts with a hooked knife before removing the bark section.
2. We apply 8,000 IBA ppm concentrate to the distal end of the girdled section. Because IBA is believed to be a possible carcinogen, the person applying the air layer should avoid contact with the solution. The best applicator we have found is the type used for PVC cement. The half-pint size is best—easier to carry and if dropped, less concentrate is lost.

   The alcohol and IBA mixture is very corrosive and rusts through the metal in a few weeks. If a coating of the PVC cement is left inside the can, the can will last much longer.
3. The air layer bag is formed by loosely filling a 4 mil 10 × 6 in. poly bag. After filling with moist peat or sphagnum moss, the open end is closed and securely tied with jute (binder twine). The jute tie material is cut so that a 4-ft. and an 8-in. end is left for later tying.

   The desired number of bags can be made well ahead at a convenient time. It is done by less skilled (and agile) workers. We have also had some made on a piece work basis at the employee's home.
4. After the branch has been girdled and the hormone applied, the air layer bag is ready to go on. The bag is slashed with the same hook knife from top to bottom and squeezed in place on the branch. Being loosely filled, the cut edges of the bag can be overlapped to help prevent the contents from drying out. The longer jute "tail" is then wound around the bag securely. First from the top down and then back up again and tied to the shorter length.

   Jute is preferred because it will deteriorate in a year or so in case the air layer is overlooked and not harvested.

In spite of our best efforts, some species root poorly or not at all. These include cherimoya, star pine, *Thevetia thevetioides*, *Casimiroa edulis*, and jaboticaba.

FUNDAMENTALS OF ROOTING TISSUE-CULTURED CUTTINGS

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Have you ever noticed that when you mention rooting of tissue-cultured plants, there is a certain "mystique" or "high tech" attitude towards it from nurserymen and growers. I know I felt the same, and still do about new techniques that I hear about.

Well, is there a lot of differences between rooting tissue-cultured shoots and standard cutting propagation? I would like to show that by applying the fundamental principles of propagation very few, if any, changes have to be made. I am going to briefly outline our procedure for rooting stage IV shoots from our Tissue Culture Lab at Briggs Nursery. I am not going to compare different systems, methods, or ideas as each propagator has made adaptations for his own crops, location, and climate. Our primary concern is to provide conditions that meet the requirements of the micro-cuttings until they root. Of course, weather and time of year are the most changeable, especially in sunny weather.

Briggs Nursery roots 95% of its micro cuttings which come from the Tissue Culture Lab right in the greenhouse so the main function of the Lab is acting as a giant stock hedge.

Once a week the Tissue Culture Lab Manager and I meet to discuss what micro shoots will come out from the lab to the greenhouse in the next two weeks. Just as in standard propagation we look to see what the shoots look like—right length, color, and specifically in this case, are the leaves developed fully? Sound familiar? In James Wells' book (1), written 30 years ago, he said, "Condition of the plant (cuttings) is the all important factor in successful propagation from cuttings."

So, by experience, we come to know the right conditions for each plant of when to cut it and bring it out. Obviously, one advantage with tissue culture micro shoots is that the lab can produce cuttings year round so the calendar goes out the "greenhouse window," except that the timing has to be right with conditions in the greenhouse.

The timing for each plant is much the same as for standard cutting propagation. Deciduous items are rooted from March onwards. This includes: *Amelanchier, Syringa, Magnolia,* and *Betula*. Slower growing evergreens are rooted July through September. This includes: *Cornus canadensis* and *Kalmia*. Other evergreens, such as *Pieris* and *Rhododendron* are rooted from September through March. Of course, seasons vary but heat and light are still the main factors for rooting. We are now doing more work with high pressure sodium vapor lights to give us more flexibility and use our space more efficiently. So far, we have seen that conditions of the wood and timing are very important.

Once the decisions have been made and we can bring the shoots out, they come either pre-cut from the lab in tubs, or still in the sterile jars. These shoots are accustomed to ideal conditions of high humidity, so we must continue this by keeping shoots cool, misted or covered with wet paper towels.

Hartmann and Kester (2), wrote "cuttings should be kept moist, cool, and turgid at all times." Rather obvious, but with shoots this size the error of margin is much less. Our planters keep the cuttings misted with Mister Squirt bottles as they plant. Possible automatic mister lines would work on a larger scale in the future.

Hygiene is very important, as in all propagation methods. We follow strict cleaning of all work benches, tweezers, and greenhouse benches with sodium hypochlorite, ammonia, or any other good cleaner, at recommended rates. We plant in 4 in. pots with new flats using a mix of fine perlite, fine peat moss, and sawdust, equal parts of each although we may use an 80/20% mix of perlite/peat for better drainage. As in standard propagation, we know certain plants need higher moisture levels for roots to form.

The first mix mentioned above is for rhododendrons, azaleas and blueberries; for *Daphne* and *Amelanchier* we use a dryer mix. These soil mixes were developed from experience obtained with standard propagation. We continue to learn and record facts from our experiments. It is vitally important to learn from each experiment. One experiment we are looking at is using paper pots as an alternative to our 4 in. pots to help with our breaking out costs at transplanting.

Planting is done in 4 in. pots at a 5 × 5 shoot spacing to give 400 plants per 17 × 17 in. flat. Larger cuttings are at a 4 × 4 spacing.

Grading is very important at this stage as "rubbish in will equal rubbish out." Micro shoots do not change this fact and through experimenting and experience one learns what inferior shoots look like for each plant. Our employees plant around 4 to 5 thousand in a 7½ hour day on piece work. Of course, good training, like any other job, is of the utmost importance.

After being misted-in they go on to the bench with a label to give us the name, stock number, date, quantity, and planter for detailed follow up.

Benches that are waiting to be filled always have mist coming on so new plants get misted when they are on the bench. It is very important to keep the moisture level up. We use biotherm heat cables to heat to around 65°F. (18°C.) at soil level. The first two weeks are important so we keep shoots well misted with mist coming on for 6 sec. every 8 min. Also, shade gives us additional protection both on the benches and in the greenhouse. We are using a "Remae" material on the benches. After two to three weeks we reduce the mist to prevent decay. This timing is obviously dependent on the current weather conditions. In the summer we use fog with mist and in the winter we use polythene tents to keep moisture levels up. We do not run the mist at night. As the shoots begin to root we give less mist and more air to give good rooting conditions. With 60 benches holding 25,000 plants each we need a full time person to water, change clocks, check nozzles, and give plants their separate needs. Again training that person in the needs of plants is a "must" here, and in any propagation system. As the cuttings root we hand water more and also liquid feed to get the right size shoots.

I walk the benches twice a week with the department supervisor to look at problems, trying to see every batch of plants. Prevention is always better than cure. We put on a fungicide and insecticide bi-weekly. Just like in any normal propagation set up, we use a rotation of chemicals to prevent immunity to buildup. Without doubt, constant watching is important to be able to meet changing conditions of these micro-shoots.

The cuttings take between 8 and 12 weeks to root. Once the cuttings are ready to move out we take them to a similar greenhouse without fog or mist. We maintain similar conditions for a week until they are hardened-off. Then we maintain the plants until transplanting time, which may be 12 weeks or 6 months depending on the time of year.

As one can see, much good basic fundamentals of standard propagation are also required in micropropagation. We do get a better plant through tissue culture, but to put roots on the shoots we still need to use many true and tested principles.

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ROOTING HARDWOOD CUTTINGS WITH BOTTOM HEAT

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At L. E. Cooke Co., a wholesale nursery located in the San Joaquin Valley of central California, the use of hardwood cuttings allows a quick and uncomplicated means of clonal propagation for trees, shrubs, understock, and grapes. Due to their quick callusing properties and rapid root initiation, plants such as poplars, willows, and pomegranates can be direct stuck as uncallused hardwood cuttings in the spring. Marianna plum, an understock for stone fruits, is planted as uncallused cuttings also. Planting in late November allows the Marianna cuttings to callus and initiate roots in winter months so shoot growth commences early in the spring.

Grape hardwood cuttings are buried upside down, in moist sand for two months to allow callusing, and often initiation of roots, prior to planting. The sun warms the two to three in. of sand covering the basal ends of the cuttings, enhancing callusing. This method of burying the cuttings upside down in sand is also used, sometimes in combination with hormone treatments, for figs and sycamores.

London plane sycamores generally callus adequately in the sand pits to allow acceptable rates of establishment in the field. Other sycamore species, such as Yarwood sycamore, oriental sycamore, California native sycamore, and Arizona native sycamore, are slower to callus and are more difficult to establish as hardwood cuttings. The latter two species do not require clonal propagation to insure blight resistance, as is the case with the Yarwood and Oriental and, as a result, the native sycamores are grown from seed as much as possible.

To enhance callusing and subsequent field establishment, bottom heat was tried on three sycamore species (Oriental, Yarwood, and Arizona native). Cuttings were made in late January and held in cold storage for three weeks. After hormone treatment (#8 Hormex, Dip N'Grow/water, diluted 1:6) and fungicidal dip (Captan) the cuttings were placed upright over electric heating cables buried 2 in. deep in sand. More sand was piled around the cuttings to about ⅓ their height and some sand was placed on top of the bundles to cover the cut ends. The cuttings were kept covered by a simple box-like structure that was open at the sides to allow ventilation yet kept the cuttings shaded to keep air temperatures cool around the tops. Outside air temperatures during the time the cuttings were on bottom heat averaged 40°F minimum and 60 to 65°F maximum. Temperature at the base of cuttings was kept at 65° to 70°F by a thermostat.

The sycamore cuttings were left on the bottom heat for approximately four weeks until planting in the field. While no quantitative observation was made, visual comparison showed that the hormone powder treatment yielded the greatest callusing and root initiation on the Yarwood and Oriental sycamores while the liquid hormone yielded the most callus and root initiation on the Arizona native sycamore. No attempt was made after planting to differentiate survival among the different treatments but response was considered significantly improved over previous year's attempts at callusing in sand pits.

The use of bottom heat to callus hardwood cuttings prior to planting out was also used over several seasons on various shrub liners such as spirea (*Spiraea* sp.), desert willow (*Chilopsis linearis*), althea (*Hibiscus syriacus*), and cistena plum (*Prunus* × *cistena*). The extra effort was made to pre-callus cuttings due to some difficulty in getting good field establishment rates when planting late. Due to wet field conditions or lack of available equipment planting-out was sometimes delayed until mid-April. In the San Joaquin Valley temperatures of 100°F are not uncommon in April, and such conditions can stress and desiccate unrooted or poorly rooted cuttings, particularly if bud break has occurred. To prepare the cuttings, immediately after collection the cuttings were treated with hormone and placed on bottom heat in a method similar to that previously described for use on sycamores. When callus formation was judged adequate, generally requiring 7 to 28 days, the cuttings were taken off the bottom heat and put in sawdust in cold storage until field planting was possible. The callused cuttings demonstrated vegetative bud break and shoot development earlier than the uncallused control, and field establishment appeared to occur more rapidly. Large increases in rooting percentage were not apparent in easy-to-root species, such as althea and pomegranate.

Desert willow, spirea, and cistena plum showed greatly improved rooting percentages under our conditions.

General observations on the use of heating cables to callus hardwood cuttings:

—Sand media gave the best results (compared to peat/perlite or sawdust) in providing moisture retention and aeration.

—Uniform distance from heating cables to cutting bases insures more uniform callusing in the bundles.

—Fungicides minimize mold in the warm, moist environment at the cutting base.

—Both liquid and powder hormone treatments proved beneficial in combination with the bottom heat.

SOME EUROPEAN TECHNIQUES FOR LAYERING WOODY PLANTS

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The practice of layering ornamental woody plants is a standard technique for vegetative propagation. It was a primary method on nurseries during the early development years of the European nursery industry in the 19th and 20th centuries. Despite recent innovations in equipment and facilities for today's modern nursery, layering still serves as an important method of propagation for some specific situations. The objective of this short paper is to outline some aspects of the different techniques used.

Layering can be defined as a method to clonally regenerate plants by allowing the development of adventitious roots while the stems are still attached to the parent plant. The shoots are then severed from the parent plant when sufficient roots have formed for successful establishment following containerization or planting in the open ground. There are two physiological principles to encourage root initiation and development on the stem. The first principle is the restriction of carbohydrates and natural auxins within a constricted area of the stem, the constriction being induced by bending, twisting, or cutting. The second principle is the increasing of the number of parenchyma cells and reduction of the amount of cell wall deposits in an area of the stem that has been blanched by excluding light. This assists in the initiation and development of roots.

Traditionally, layering was used for many woody ornamentals, e.g., *Magnolia, Hamamelis, Acer,* and *Rhododendron,* while today it is used primarily for rootstocks, e.g., M.M. 111 and *Prunus* F12/1. Layering is a long term investment in land, labor, and plant material, and therefore there are a number of important criteria that any nursery should consider before contemplating a layering enterprise. In the end, it comes down to economics based on whether it is more efficient to use layering for individual species compared to alternative methods. In the majority of cases, alternative methods are now selected.

Stooling (mound layering) is the technique most widely used today—in particular for tree rootstocks. In the past, it was an effective method for *Chaenomeles japonica* cvs., *Daphne cneorum, Prunus glandulosa* cvs. and *Pterocarya fraxinifolia.* It is by this technique that innovations by creative nurseries and researchers have dramatically increased yields and productivity. Soil fumigation and the availability of virus-tested material are two reasons why yields have increased, while improved mechanization practices have dramatically increased efficiency. For example, instead of the traditional shovel for mounding soil, custom-made machines have been constructed which combine the effect of a land-driven rolling-tined cultivator with that of compressed air from an air blast spray. The soil is moved into and around the bases of the shoots by having the cultivator at different settings while the compressed air keeps the shoots vertical. Similarly, the productivity in harvesting layers has been significantly improved by severing the rooted stems below soil level with a tractor-mounted power-driven saw blade controlled by a hydraulic depth control.

A more recent modification to the usual stooling method follows a North American practice by adapting a standard procedure used successfully in the formative years of an etiolation layer bed. The mother rootstock is planted at a 30 to 45° angle and a custom-made hand tool is used to lace twine, held in position with hop clips, over the main stem during the summer of planting or the next spring. This method is used instead of the customary pegs and wire to retain the stem in the shallow trench. The normal procedures for mounding up the soil are implemented in subsequent years. Experience has demonstrated that heavier yields are produced during the early years of the stool bed—for example, one specialist nursery in England achieved an 80% improvement in yield of rooted stems in the third year compared to the traditional planting and establishment procedure.

Etiolation and trench layering have been used on *Morus* and *Juglans*, but were the standard technique for producing *Prunus avium* Mazzard F12/1 rootstocks. One major problem that has led to the lowering of quality and yield of some *Prunus avium* Mazzard F12/1 layer beds is the build-up of soil-borne diseases—particularly specific cherry replant disease (*Thielaviopsis basicola*) and crown gall (*Agrobacterium tumefaciens*). These disease problems, plus the introduction from East Malling Research Station of the popular *Prunus* 'Colt,' normally propagated by hardwood cuttings, has significantly reduced the acreage of etiolation layer beds in Britain.

The standard procedures for simple layering and continuous (French) layering have changed very little over the years. However, they still serve as a very important method for some European nurseries and recently I saw layer beds being established on some *Acer* and *Tilia* species in England. Even with today's modern propagation facilities there are situations whereby simple layering of *Acer, Corylus, Magnolia, Platanus, Rhododendron,* and *Syringa* can still be economical for some nurseries. The major problem is the inability to mechanize the production, resulting in a considerable amount of hand labor. The techniques of serpentine, drop, and air layering are now rarely used commercially. (A series of slides was shown to demonstrate the traditional procedures used in Britain, Holland, Belgium, and France).

Looking to the future, layering of ornamental woody plants is likely to decrease further as technology develops. The major limiting factor is the area and cost of land required. However, stooling for rootstocks will remain a standard propagation method. Further innovations in machines, fumigation, pesticides, and overall plant health will produce even greater improvement in quality and yields. Layering procedures are part of a wonderful history in the European nursery industry, but there are specific circumstances, even with today's changing technology, where layering will still have its virtues for many decades to come.

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AVOCADO CLONAL ROOTSTOCK PROPAGATION

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BACKGROUND

Until 10 years ago, nearly all orchard-bound avocado trees raised in California were on seedling rootstocks. Clones were used only for fruiting scions such as Hass, Fuerte, and Bacon. Since 1977, however, some half million trees have been planted on clonal rootstocks. It's my guess that avocado tree production today is split about fifty-fifty between seedling and clonal rootstocks. How has this come about?

The stimulus for the newer commercial technologies came from Dr. George Zentmyer who was working toward the solution of a serious disease, avocado root rot, which first came to avocado growers' attention during the late 1940's. During the 1950's it occurred to industry leaders that this disease, caused by *Phytophthora cinnamomi* (Pc), was a serious threat to the entire avocado industry. Zentmyer, in a search for tolerant rootstocks, Holland, Belgium, and France).

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Fortunately, the basic technology was at hand. Ted Frolich, working with rootstock specialist, Dr. F. F. Halma, in the 1940's had discovered that stem tissue of avodado rooted well provided that the stem was etiolated. This discovery, coupled with Ted's expertise, enabled Zentmyer to utilize some two thousand clonally rooted avocado trees (grown by Frolich) in order to evaluate and select the best of his Pc-tolerant candidates (1).

Commercial nurserymen responded to these developments in the early 1970's when it became clear that the Halma-Frolich-Zentmyer group had discovered something really significant, that these discoveries offered a possible solution to the avocado root rot threat.

At Brokaw Nursery we endeavored to duplicate Frolich's technique with limited success. We tried variations on the technique, and, in the course of time, struck upon a procedure that has enabled us to produce more than 100,000 of these trees in a single season. While incorporating Frolich's basic discoveries, this technique departs sufficiently from his procedures that we were able to patent the process for avocados (U.S. Patent No. 4012866).

The purpose of this paper is to describe the practical application of this newer process. It will not cover general avocado tree production practices, such as general phytosanitary precautions, etc., as these were outlined in an earlier paper (2).

THE PROCESS

Seed Selection, Treatment, and Planting (Duration: approximately 3 weeks). We use large, vigorous seeds in this process because the plant, in all its propagation phases, will receive much of its energy and hormonal supply from this source. We have found that the very best seeds are from West Indian (i.e. 'Waldin') or West Indian × Guatemalan (i.e. 'Lula') sources. Certain Guatemalan seeds may be used as well, such as 'Hazzard' and 'Fourth Generation Hass.'

After heat treatment the seeds are scarified on the basal end, bedded for sprouting, and selected for planting into polyethylene bags with drainage holes, which are especially designed for the purpose (Figure 1). They are planted with the apical end flush with the sides of the containers.

For bedding, planting, and rooting we use a peat-perlite blend.

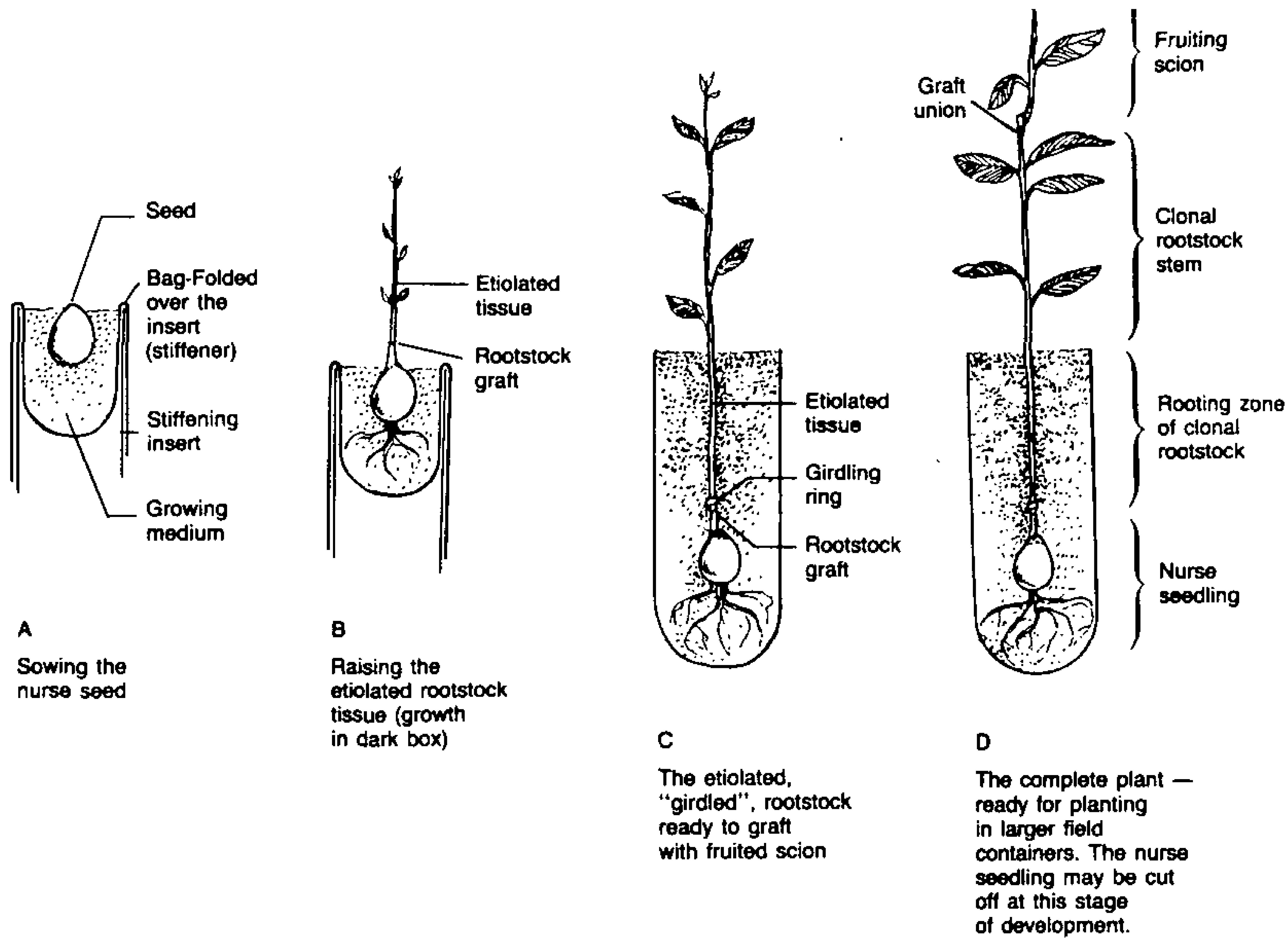

Figure 1. Use of the propagating bag. The 12 inch (30 cm) long poly bag is used for all propagation stages. At seed sowing, rootstock grafting, and etiolation it is in the "folded" state and supported by a disposable insert which serves as a stiffener. After "girdling," the bag is extended, the insert discarded, and the bag is filled to the brim with a growing medium.

Propagating the Rootstock. The seed and seedling will be henceforth referred to as "nurse seed" and "nurse seedling" since their sole function is to temporarily sustain subsequent grafts which will serve as rootstock and fruiting scions of the producing adult avocado trees. The nurse seedlings will die in the process.

Once the nurse seedling has grown to a height of approximately 10 in. it is ready for a rootstock graft. Any convenient grafting technique will serve. At our nursery we use a simple split stem and wedge-shaped scion, but a whip graft and sundry variations will serve equally well. The only special requirement is that the graft be placed low on the seedling stem. We want the roots to originate as near as practicable to the nurse seed but on the rootstock shoot which will emerge from the rootstock graft.

After the rootstock bud has emerged, possesses obvious vigor, and is ¼ to 1 in. (0.5 to 3 cm) in length, it is transferred to a dark chamber for etiolation. Within the chamber it is allowed to grow to a height of approximately 14 in. (35 cm), at which time it is removed for hormone application, girdling, and bag extension, the extended bag finally to be filled to the brim with a suitable propagation medium (Figure 1).

Hormones are applied by brush to the etiolated tissue to a height of approximately 6 inches above the nurse seed. We use an alcohol-water solution of 2000 ppm IBA and 1000 ppm NAA. This hastens rooting but is not essential to the success of the process.

Once the hormone solution has dried, we encircle the rootstock scion at its base with a loosely fitting metal ring ¼ in. (½ cm) or more in width that has no gaps. In practice we use a "C"-shaped metal band that is clamped around the original rootstock graft. If it fails to close completely we add another whose gap is opposed to that of the first (Figure 2).

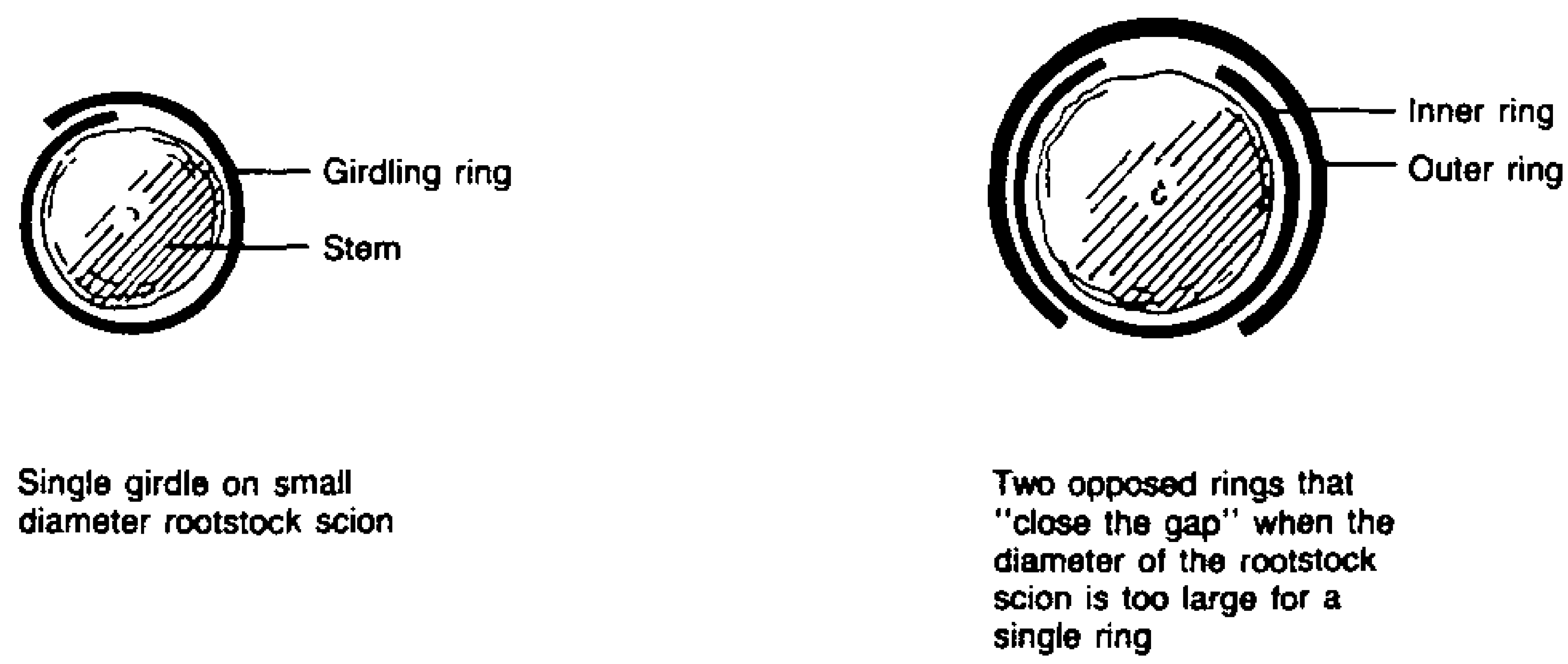

Figure 2. Girdling rings. In practice, the gaps of these rings are closed tight with pliers or other suitable instrument, taking care not to crush the cortex of the stem.

The purpose of this ring, which we call a "weaning girdle," is to gradually constrict and extinguish the life from the nurse seedling after our propagations have been completed. The nurse seedling normally dies within a year, when the tree is still in the nursery. In some cases it is tenuously alive at time of delivery, but never have we seen one with life after two or three years from seed planting.

Other types of metal strictures may be used as well. Broad washers may serve, since they also require substantial overgrowth by the stem to reestablish any connection between nurse seedling and the grafted rootstock. Rubber or plastic will not reliably serve. They are apt to be overgrown, thus allowing reconnection of the nurse tissue with the clonal rootstock stem.

Once the hormone is applied and weaning girdle is in place, our bag is extended (Figure 1) and filled with the propagation medium. We are now ready to graft a fruiting scion onto the clonal rootstock stem. This may be done immediately onto the etiolated tissue, or it may be delayed until roots have emerged.

Propagating the Fruiting Scion. This operation is straightforward and may be accomplished by any appropriate technique. We use the same wedge graft that was described above for rootstock grafting.

In practice, we graft fruiting scions at a height of 8 to 10 in. (20 to 25 cm) so that in case of graft failure (some 3 to 15% of grafts may fail) we can regraft at a lower height. We pinch sprouts (shoots on the rootstock) but are careful not to completely remove them below the basal ring. (The live shoot stubs, with their basal buds, maintain "sap" movement up and down the rootstock stem. I believe that in the process they preserve a functional hormone balance.)

The grafted plants are usually kept in the greenhouse for a period of 6 to 10 weeks, frequently sorted to prevent shading, and then transferred to a shade house.

After two weeks in shade and a few days in open sunlight they are ready to be planted into the larger 3½ gal. containers (14 liters) in the field, or outside growing grounds, in full sunlight. Transplanting procedures are standard and are described in an earlier publication (2). These larger outside containers previously have been filled with a soil-organic mixture which drains well, yet is somewhat cohesive and has a suitable ion exchange and water retention capacity.

TIMING THE PROPAGATIONS AND ENVIRONMENT

The timing of avocado propagation is critical. The nurseryman needs large quantities of fresh grafting materials when they are in optimal condition. At Brokaw Nusery we raise 8 rootstocks and 7 fruiting cultivars as standard offerings, each with its own timing requirement. Grafting material is generally available during periods of the winter so that all our propagation operations are performed in the greenhouse.

To illustrate the timing problems: in Ventura County, California, 'Duke 7' is best grafted from late October to early February. 'G755,' on the other hand, often causes problems when grafted before mid-January. 'Hass' scionwood is best from January 15th to early May. The reader can see that the timing of production is specific to cultivar and is a delicate matter if one is to achieve a high success rate with a large number of plants.

NURSE SEED ATTACHED

Our method is sometimes referred to as the NSA, or Nurse-Seed-Attached, method, and has troubled some individuals who have suspected that it is not a purely clonal rootstock.

It would be a simple matter to completely prune off the nurse portion of the baby triple-staged plant before field transfer. Indeed we would, were we not fully confident that the nurse portion would finally die while the plant is still very young. The nurse seedling does inevitably die, however, and we consider it to be of positive value during the full course of its brief existence. It assists plant development for a period of 6 to 10 months from seed sowing.

LIFE CYCLE OF THE DEVELOPING PLANT

Normally our trees are delivered for spring orchard planting at 16 to 20 months after sowing of the nurse seeds. At this time the plants have been trimmed to a height of about 38 in. (95 cm). Sometimes they are delivered in the summer at ten months, in which case they have reached heights of 30 to 35 in. (77 to 90 cm).

About six or seven months of the plant's life is spent in greenhouse, shadehouse, and in outside storage prior to transplanting in the field. The stages of development for most saleable trees may be broken down as follows:

Seed sowing to planting	3 weeks
Development of seedling	3 to 5 weeks
Rootstock bud start	4 to 6 weeks
Residence in etiolation chamber	3 to 5 weeks
Staging for scion grafting	1 to 6 weeks
Scion graft development	4 to 8 weeks
Hardening period	2 to 6 weeks
All time prior to field nursery	19 to 41 weeks (sum of the above)
Time in field	40 to 70 weeks (approx)
Total time	69 to 87 weeks (16 to 20 mo.)

FUTURE OF CLONAL ROOTSTOCK PROPAGATION FOR AVOCADOS

New avocado rootstocks are being introduced on a regular basis and I do not foresee an end to clonal propagation. As we continue to progress in our evaluations of new candidates we will inevitably find higher levels of Pc-tolerance and discover superior combinations of other horticultural characteristics—such as salt-tolerance, chlorosis resistance, controlled tree size, frost resistance, and superior cropping. Indeed, cultivar differences are already showing up in some of these areas. I expect that, down the road, we will be using specific rootstocks matched to specific fruiting cultivars and to specific soil-water quality combinations.

The stage is set, then, for a germplasm search of unprecedented proportions, as we search for the ever evasive perfect rootstocks and rootstock-fruiting cultivar combinations. It will be an exciting period for several years. It's a great time and fertile opportunity for the progressive avocado nurseryman.

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VOICE: In air-layering, do you use any dark-colored foil to cover the plastic over the root ball?

WM. NELSON: Yes, we do, using the darkest color we can find, although with the plastic alone we can get some heating, which is good unless the weather gets too hot, when there can be scorching of the roots.

VOICE: In girdling your branch for air-layering, do you not lose the entire branch if the layering is not successful? Also what time of year is the air-layering done and what size branch is used?

WM. NELSON: In southern California, where the growing season is virtually the year round, we can do air-layering successfully almost anytime. And with an active cambium at the girdled area it will callus and heal back together, even on a 3 or 4 in. diameter branch—so we do not lose it. We work with branches from about ¾ in. to 2 in. in size for our air-layering, but the branch size is not as important as some other factors. A good root system should form on air-layers in 2 to 3 months.

VOICE: Question for David Hill. What type of lighting are you using for rooting your tissue-cultured cuttings?

DAVID HILL: For the past several years we have been using mercury vapor lamps at 150 foot-candles at bench level, but now we are looking at high pressure sodium lamps, which will double the foot-candle output.

VOICE: First a comment on air-layering. We have found that a Windex type sprayer or an aerosol sprayer can be used to apply IBA solutions to the girdling cut on air layers. Now a question for Bill Nelson. What total costs per unit are involved in your air layering techniques?

WM. NELSON: For the rare, expensive, specimen trees that we air-layer on someone's property we pay the owner five dollars per tree, leaving the tree in good condition. Total costs for an air-layered plant into a container would be about $15 each. For this we would charge $40 per tree.

INTEGRATED ARTHROPOD PEST MANAGEMENT IN PLANT TISSUE CULTURE PRODUCTION

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Arthropod pests commonly associated with plant tissue culture production include thrips, mites, ants, and cockroaches. The first two are particularly troublesome for several reasons. First, their small sizes allow them to go undetected for a long period of time. Second, they have a tremendous reproductive ability and can build up to large numbers within a relatively short period of time. Last, they often are found infesting tubes and jars inside the incubation area which may necessitate destruction of a large portion of the stock. The other two, ants and cockroaches, are frequently found in transfer rooms and surrounding outside areas. They are largely scavengers and may be physically excluded from buildings.

BIOLOGY AND IDENTIFICATION

Thrips. Several thrips species may be found infesting tissue culture plants. Of the more common are the western flower thrips, *Frankliniella occidentalis* and the onion thrips, *Thrips tabaci*. Thrips are minute, slender insects which vary in color from tan to dark-brown or black. They possess a pair of feather-like or fringed wings which they hold flat over the body when at rest. Eggs are laid in plant tissue. There are two nymphal and two resting (pupal) stages. Life cycle can be completed in 3 weeks or longer depending on the species. Thrips damage plants by scraping the tissue with their single mandible and lapping the juices. This activity usually takes place in the protected, growing tips of the plant. When the tissue expands, leaf deformities and cupping are evident as a result of feeding by thrips.

Mites. Mites are the other troublesome group of pest arthropods found in tissue culture production. Mites are not insects. They can be separated by lacking wings and possessing one body segment and four pairs of legs (with the exception of gall mites which have two pairs of legs). Insects have three body segments and three pairs of legs, and they may or may not possess wings. Dust or fungus mites are usually found in containers in the incubation room. Even though some may be airborne, it seems that the majority of infestations become started through passive movement on workers clothing and other infested materials.

Several tactics must be employed when devising an integrated pest management strategy. A combination of physical, cultural, and chemical methods must be carefully tailored for individual situations.

Physical Methods. The foremost concept of physical management is exclusion. This means that barriers must be used to prevent the pest arthropod from gaining access to the growing environment. Screens must be installed on vents to prevent entry. Regular window screens or fiberglass screens may not be appropriate due to their coarse texture. Finer-mesh screens such as paper filters (5 μ) or 200-mesh cloth screens must be used to insure exclusion of small insects such as thrips. Screens should be changed as needed, perhaps as often as once a month.

Evaporative coolers tend to introduce insects in their air stream from the outside environment. Therefore, the use of internal coolers is preferred to eliminate that route of pest introduction. Recirculating air filters (such as "Hepa" filters) also are useful in trapping dust, particulate matter, and other contaminants in the transfer room. This will allow for a cleaner environment and a lesser chance of contaminants being introduced into the incubation room.

Cultural Methods. Sanitation or asepsis are imperative to any tissue culture production operation. Use of sterile techniques, especially in the transfer room, would prevent establishment of several contaminants (1, 3, 4). The use of clean stock also reduces the chances of introducing a foreign organism into the culture.

Worker clothings must be regularly cleaned and thoroughly inspected before entry into the incubation room. Workers with bright colored clothes should be required to change their clothes before entering transfer or incubation rooms. Bright colors, especially yellows, are attractive to flying insects which may then be passively carried indoors.

Temperature regulation and air circulation also are important cultural factors. Extremely high temperatures are undesirable since they result in plant stress, as well as being conducive to rapid arthropod population increases. On the other hand, extremely cool temperatures may retard plant growth and development. Therefore, the proper temperature range for the plant species should be maintained as well as an appropriate air flow which results in an equitable temperature distribution.

Monitoring pest arthropods is another crucial cultural practice. Periodic visual inspection of containers will reveal infestations early. Additionally, flying insects, such as adult thrips may be attracted to yellow sticky cards hung in the transfer and incubation rooms. These cards must be monitored weekly for infestations and changed as needed. It is important to keep in mind that the cards are being used as an early indicator of infestations. They cannot be relied upon for complete control by attracting all thrips since the wingless immatures are feeding inside the containers. Once an infestation is detected, appropriate chemical control or disposal of stock must be carried out for eradication.

Chemical Control. Pesticides may be used against arthropods, either as a preventative or a curative measure. Indoor foggers (such as "Holiday," "Black Flag," etc.) may be used once a month in the transfer room. They usually contain a pyrethroid insecticide which results in quick kill. The carrier particles, however, may clog up the recirculating air filter. Therefore, it is advisable to turn off the filter prior to fogging over night. Systemic insecticides may be incorporated in media if they are stable under autoclaving. A successful example of this use was given for the insecticide acephate (Orthene) by Klocke and Myers (2). They reported excellent control of thrips, *Allothrips* sp., with as low a concentration as 10 parts per million.

The use of fenbutatin-oxide (Vendex) for mite control has been reportedly successful. Various growers have experimented with painting shelves with a Vendex paste for mite control. Results seemed acceptable when this was carried out every six months. However, neither acephate nor fenbutatin-oxide are currently registered for such uses.

Finally, ants and cockroaches may be excluded from indoors by sealing all cracks and crevices and following sanitary procedures. External perimeter applications of pyrethroid insecticides such as cypermethrin or permethrin will repel ants for long periods. Boric acid powder ("Roach Proof") has reportedly been successful for cockroach control when applied alongside bases of walls and shelves. "Combat" bait stations also may be effective against cockroaches indoors.

It appears from the above that proper physical and cultural practices should suffice to prevent an arthropod infestation. Chemical control may be used when a large infestation is detected or when destruction of the crop is not feasible.

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COMMERCIAL MICROPROPAGATION OF *KALMIA*

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Kalmia latifolia (mountain laurel), can be propagated by seed, grafting, cuttings, layers, or micropropagation. By far the easiest method of propagation is by seed. But for clonal reproduction, micropropagation is clearly the most successful mode of propagation.

Within the last five years nurserymen have seen literally an explosion of new introductions. This is partially due to market demands, but also it is due to the ability to dependably propagate *Kalmia* in large volume. The 1980 paper by Lloyd and McCown (1) presented a protocol for successful micropropagation of *Kalmia*. The nursery industry has benefited greatly from these and other researchers.

Within the last 5 years, Richard Jaynes has produced several new introductions of mountain laurel with improved flower, foliage, and plant characteristics.

Why micropropagate or use tissue culture to propagate Kalmia? Micropropagated *Kalmia* are own-rooted, true-to-name, vigorous, and have superior branching. Large numbers of *Kalmia* can be produced quickly. This facilitates the rapid introduction of new selections.

To succeed at micropropagating any plant, we believe a sound horticultural understanding of the plant is important. Firstly, *Kalmia latifolia* is a member of the Ericaceae family, requires cool, moist, acidic but well-drained soils. In the wild, mountain laurel is often found as an understory shrub along slopes, streams, or pastures. *Kalmia* thrives with moderate fertilization but can be easily injured or killed under conditions of high fertility.

Kalmia can be initiated in tissue culture from shoots from stock plants any time of the year. But we prefer to use green-wood stems from greenhouse-grown material. Shoots are defoliated carefully, so as not to injure the lateral buds on the stems. These shoots are then washed in running water for up to 30 min.; next, 7 to 10 washed shoots are placed in glass jars filled with 400 ml of water with 1 drop of Tween-20 and agitated for 10 minutes. Finally these shoots are placed in 400 ml of 10% laundry bleach (0.05% sodium hypochlorite) and agitated for 15 to 30 min. The explants are next placed in 1% laundry bleach. These shoots are then either trimmed into smaller sections or trimmed just to remove damaged tissue and placed in test tubes with liquid or solid woody plant medium (WPM) supplemented with N^6-(2-isopentenyl)adenine(2iP) (1).

Cultures are grown under cool-white fluorescent light (50 to 70 μmol $s^{-1}m^{-2}$) with a 16 hour photoperiod. The culture room temperature is regulated at 23°C±1°C. Shoots are grown on solid media in 25mm × 150mm test tubes or glass baby food jars.

Depending upon the timing and condition of the stock plant, new growth appears from lateral buds within 4 to 8 weeks. Once new growth appears, plants are subcultured on to solid WPM with 2 to 10 μM of 2iP. As we grow more selections of mountain laurel, we find that the specific growth regulator and its concentration may need to be adjusted for recalcitrant clones. Some researchers automatically include an auxin with every medium they test. We believe auxins are of no benefit in the shoot multiplication stage for *Kalmia*.

In general, mountain laurel responds very well to 2iP. A 13 to 15× multiplication rate is not uncommon. However, *Kalmia* can become easily habituated at these high cytokinin levels. Both leaf and shoot quality and rootability will suffer. We recommend to keep a multiplication rate of approximately 5×.

Plants are subcultured every 8 to 12 weeks. We have not noticed any decline or degeneration of cultures that others report (2). Perhaps this decline may be due to a gradual increase of a low level contaminant. We have some clones of mountain laurel in culture that are over 8 years old.

Cultures may be refrigerated when not needed. Sealed containers are placed in a dark refrigerated area at 3°C±1°C. Mountain laurel will remain viable for one to two years in this environment. Rooted plantlets in culture may live longer.

Kalmia can be rooted in the laboratory or in the greenhouse. We choose to root most all our *Kalmia* in the greenhouse. Microcuttings or cultures are sent to the planting crew and 25 shoots are stuck in a 10 cm square pot. The soil mix consists of equal parts of peat moss, perlite, and Douglas fir sawdust. The untreated cuttings are misted, placed in tents or are fogged, depending upon the weather and time of year. We start rooting mountain laurel in April or May and finish by October. It is not uncommon to get 80 to 95% rooting. Rooting occurs within 4 weeks. It is very important that quality microcuttings be produced to achieve these results.

Variation in rooting can be attributed to: the quality of the microcutting, timing, weather, a water or humidity problem, or soil mix aeration. Mountain laurel foliage becomes red when it is under stress. When the plants are large enough they are potted and grown on into liners. The plants are treated and respond like seedlings.

In order for commercial micropropagation to be a success, good business decisions and a sound management team is a must. Obviously, it would be easy to overproduce these items. However, the demand is not nearly as high for a particular selection of *Kalmia* as, perhaps, a *Syngonium* or *Ficus*. The major advantage of using micropropagation for mountian laurel is not production of large numbers, but rather dependable production of new and old selections. Micropropagation has allowed *Kalmia* to move out of the arboreta and breeder's fields to be enjoyed and appreciated in landscapes and backyards around the world.

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2. Bennett, L. 1987. Tissue culturing redbud. *Amer. Nurs.* October 1:85–91.

SOME IDEAS IN PLANT PROPAGATION: CUTTINGS AND GRAFTS (MOSTLY ROSES)

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Most likely much of what I am about to say is "old hat" to many of you. However, we can all learn something new or give an old idea a new twist. All too often we see something or get an idea but fail to follow it through. Sometimes we are too busy to bother or the idea fails to "click." Often we are just not ready or have no need at the time.

We know how to do many things in the nursery business but someone is always coming up with a different idea or a new need arises. Often an idea which may have been impractical at the time can come to life because of new materials. Rooting hormones, misting, plastic materials, etc. are some of the developments which have made older ideas more practical.

For many years I have worked at propagation (mostly roses) and have come up with several innovations . . . some original, some borrowed. Some ideas come about by accident and others out of necessity. Now I would like to go down my list of helpful ideas for the propagation of roses and other plants. I have worked with other kinds of plants and still do. My plant breeding work has covered a wide range of interests. I started with roses and they are still a top priority with me. But I have also worked with such plants as zinnia, cosmos, plum, cherry, gloriosa daisy, and crape myrtle.

In this work I have had to learn and use numerous ideas and techniques in plant propagation. First, there are seeds. Each species and (often) cultivar has special demands. In my work with dwarf micropropagation for mountian laurel is not production of large numbers, but rather dependable production of new and old selections. Micropropagation has allowed *Kalmia* to move out of the arboreta and breeder's fields to be enjoyed and appreciated in landscapes and backyards around the world.

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In this work I have had to learn and use numerous ideas and techniques in plant propagation. First, there are seeds. Each species and (often) cultivar has special demands. In my work with dwarf crape myrtle, harvesting and cleaning seed has its special requirements. I learned that often some of the best parents shed their seed too soon, or the seed capsules would not open properly, in which case it was necessary to crush the dried capsule to release the seed.

Some plants propagate easily from either soft or hardwood cuttings. Others need special care, preparation, timing, planting depth, light and moisture conditions. Some of these are learned by experience or through reading or training. Often the grower learns by close observation. Often the plants themselves seem to be trying to tell us something and it pays to become a keen observer.

In my work I have dealt with propagation from seeds, from cuttings, and by grafting. So I would like to make some observations and suggestions; to tell you some of my experiences in the field of plant propagation.

First, as all propagators know or must learn, there are several different kinds of cuttings and grafts . . . different methods to produce another plant. Many plants can be propagated easily and inexpensively from hardwood (dormant) cuttings. But I want to discuss mainly the propagation of roses (and other plants) from softwood or "green" cutting material. By "green" I mean wood of the current season's growth with leaves. Such cuttings may be made and rooted over most of the growing season if given proper care and conditions.

In roses (miniatures especially) the soft growing tip and material immediately below this makes excellent cuttings and roots quickly. Cuttings may be 2 to 4 in. in length. We do not remove leaves. The bottom cut is made just below the bud. If cut even ¼ in. below the bud the cutting takes longer to root. There are also several other ways the cuttings can be made or prepared for rooting: [1] Use a small length of twig (I like cuttings with 2 or 3 buds, and leaves). Shorten the leaves to save space and help prevent leaf drop. It is essential to have at least one leaf on each soft or green cutting. [2] Use a similar cutting except the base is cut at a sharp angle. This induces more downward rooting. [3] Prepare a "Slice" cutting in which a cut is made deeply into the wood near the cutting base as though you were taking out an eye for budding but do not cut it clear out. This heavy wounding will induce rooting. [4] Use the old fashioned idea of just splitting the cutting base. [5] Wounding: cut or scrape the side(s) of the cutting just above its base. [6] A "chip" cutting, in which a chip—like a heavy bud (with leaf and bud eye)—is cut out and rooted under mist. [7] Prepare a short, single bud cutting (1½ to 2 in.) with bud and leaf at top. [8] Use short cutting like above, only the leaf and bud are at bottom of cutting, using the wood (1½ to 2 in.) above the eye as a handle; this cutting will root quickly and better than the above.

Another propagation method is the budded cutting. One must have available a healthy, vigorous understock plant, producing long succulent canes suitable for budding. If done late in the season and cuttings are to be used "dormant", all leaves may be stripped off the cane before budding. Buds are allowed to heal in and the canes made up into cuttings during the winter. Remove all unwanted buds before planting. Good plants can be grown in one season by this method.

If the canes are to be made into cuttings as soon as buds take, at least one leaf must be left on each cutting. Another reason to use the cane bud method is to "store" buds of some new or rare cultivar (on canes) for later use.

To hasten rooting of cuttings, the stock plant (from which cutting is to be made) may be wounded by girdling (making a knife cut around the branch or twig) and covering with black tape until the callus beneath the tape is well formed. Remove tape and plant in a rooting medium. Another type of wounding is to remove a bit of bark 1 to 2 in. long from one or both sides of the shoot and cover it with black tape as above. These methods work well with rose, camellia, redwood, plum, and metasequoia.

We grow quite a number of miniature tree roses and now use a budding technique which I saw in South Africa several years ago. Instead of making a T-cut and slipping the bud under the bark flaps, this method only requires a very shallow cut to remove a sliver of bark (we leave a bark flap about ¼" long at top of this cut) then a similar sliver (skin bud) is laid over the cut, tucked under the short flap, then tied in with Parafilm. This works very well for us.

Another variation of the above, when used outdoors in hot weather or if the bark is thick, is to tie the bud in with Parafilm, then overwrap with a rubber budding strip. This holds for a longer time and in closer contact when the stock and/or buds are heavier, thus insuring a good "take." I have done this on dormant cherry with 100% success.

To produce many cuttings from a rose plant we have used the following method for hybrid tea, floribunda, and others: Grow the stock plants in containers and keep them in vigorous soft growth. As flower buds appear they are pinched off to force vegetative growth from buds at each leaf. One to 3 soft, single bud cuttings (as mentioned earlier) may be taken as soon as growth from each leaf reaches 1½ to 2 in. in length. In a few more days another cutting or two may again be ready. This process is repeated and new canes from the base arise to replace those used up. If watched carefully many cuttings can be produced in this way, thus increasing a cultivar rather quickly.

Another method I use to hasten my rose breeding (and shorten testing and production time) is to use seedlings from my crosses. There are usually a number of discards . . . climbers which do not bloom or whose flowers are poor. These can be used as "clean, virus-free" understocks on which a promising seedling may be budded. To test out a possible hanging basket or groundcover cultivar I usually bud at 24 to 36 in. For others, 8 to 12 in. is adequate. This gives a good idea of the shape, flowering and growing habit of a new selection, and can supply more propagating wood in a short time.

A variation on the above is to use rooted *Rosa multiflora* cuttings grown from clean virus-free material. I like to have a plant that is grown from a de-eyed cutting (leave 1 or 2 eyes at top) which heads out about 6 or 8 in. above the soil line (in pots). From this numerous shoots will grow. I select the strongest, removing all buds possible up to the height at which I wish to bud. This fast growing cane is easily budded and the "take" is usually excellent.

Other ideas: roses can be grown by grafted cuttings in which a short cutting (*R. multiflora* or any easily-rooted stock) about 4 or 5 in. long is made, leaving 1 or 2 leaves at top. All other buds are removed. Then a deep slanting cut downward is made in the understock (about 1 in. from base) into which a wedge-shaped scion is placed. This scion may have only one bud and leaf. We wrap with Parafilm, as the graft then heals much better.

SUCCESSFULLY GROWING PROTEACEAE

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This paper will cover growing of Proteaceae transplants, propagation by both seedlings and cuttings, transplanting, and cultural aspects, including soils, fertilization, and disease control.

PROPAGATION

Seedling Propagation. Our experience began with seeds of members of the Proteaceae family purchased from Australia and South Africa. We attempted germination in seed flats, and encountered the first problems with seedling propagation—seed dormancy. Many dormancy factors are built into different kinds and/or populations of Proteaceae seeds. Most Proteaceae plants are native to Mediterranean climates and seeds tend to germinate best in the cooler rainy seasons when ample water is available to the young seedling.

Seed scarification in Proteaceae plants (6) has been found to improve germination rates. Stratification (5) of seeds at 5°C for 30 to 60 days prior to planting improved germination rates. Oxygenation virus-free" understocks on which a promising seedling may be budded. To test out a possible hanging basket or groundcover cultivar I usually bud at 24 to 36 in. For others, 8 to 12 in. is adequate. This gives a good idea of the shape, flowering and growing habit of a new selection, and can supply more propagating wood in a short time.

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(2) by soaking the seeds in 1% solution of hydrogen peroxide for 12 to 24 hours improved germination. We found seed freshness to be of utmost importance in obtaining high germination percentages.

Seed germination rates vary widely among cultivars of the same species and certainly among different species and genera. The root growth that we found on seedlings was surprising. At the time of cotyledons only, with no true leaves expanded, we had as much as six inches of tap root growth and by the time the first true leaves had expanded well over a foot of tap root growth had occurred.

One problem that seeds bring with them are diseases. Seed-borne diseases have been introduced into California. Luckily California's dry environment is not supportive of many of the diseases, although the moist nursery environment can be.

A seed treatment has been recommended to minimize many of the seed-borne diseases, which include *Dreschlera* spp. and *Colletotrichum gloeosporioides*. The treatment is as follows: A hot water soak at 50°C for 30 min. followed by dusting with a fungicidal powder.

Cutting Propagation. The rooting medium should be free-draining, in acid in reaction, and sterile. Semi-hardwood material is the preferred type for cuttings. This usually develops in shoots that are 4 to 9 months old on the mother plant. Some wood as old as 18 months can be rooted by the use of higher rates of hormonal treatment. IBA is the best rooting hormone, and both powders and liquids have been effective in concentrations from 2,000 ppm to 8,000 ppm. Fungicides have not appeared to be detrimental when mixed in with powdered IBA. Some *Protea* species were sensitive to NAA as a rooting hormone (3), and we have limited its use to experimental treatments.

Bottom heat can initiate callus and roots quickly in some species (1). Many of the hard-to-root cultivars are kept on bottom heat for rooting; in some cultivars i.e. *P. repens* bottom heat is detrimental (3). Although it is not recommended, most *Protea* we grow is rooted on bottom heat. The frequency and duration of misting is quite variable among the many cultivars. Some do best if moistened once a day, with the rooting medium remaining dry; others require both regular misting and a moist rooting medium.

A general rule we use is an average of once per hour misting for 5 to 10 sec. at 19°C, with 70% humidity. Some indication can be obtained by the geography of the origin of various populations and how hot or moist their native environment is as to how much misting the cuttings require.

Transplanting. As with most crops, the handling of the transplants is very important. Our primary failures during transplanting were minimized by using a "plug" system. The roots remain undamaged or minimally damaged during transplant. The soil medium we use has always been a quick-draining acid mix. Over-potting has been less successful than a plant "sized" to a container.

We selected deep "sleeves" that give air pruning. The plants in the "sleeves" are kept up off the ground to allow for air to prune the roots. They do not become rootbound. We try to transplant once a year.

Proteas that become rootbound have extreme difficulty adapting to other soils, even more so than other ornamental plants. We have found shade to be valuable in minimizing the shock at transplant. Transplants are held in shade for approximately 4 to 6 months or until adequate root system is developed in the new container medium and then they are moved into a full sun position.

Fertilization. Fertilizer is incorporated into the water and applied to each plant at every watering. Fertilizer concentrations are generally at a half rate compared to other ornamentals and no phosphate or potassium is used. Phosphate toxicity symptoms can develop rather quickly. We withhold nitrogen fertilizer from most of our plants during the late fall into early winter to avoid the tender growth that can be damaged by frost.

Pests and Diseases. Luckily most insect problems on our Proteaceae were left in the southern Hemisphere, although aphid, worm, scale, and thrip damage can be found among Proteaceae. Most of the disease problems that we do have in California are directly related to soils or lack of air circulation. The soil medium should be quick-draining as this tends to minimize the amount of *Phytophthora* and other soil pathogens. Good air circulation is very important for control of foliar fungi. Our nursery is primarily under shade cloth and allows for good air movement. Watering is generally done by a time clock in the early morning. Good air movement dries the leaves and we have a minimum of foliar fungi, although those listed below can occur.

1. *Colletotrichum gloeosporioides* infects, but is not limited to the genus *Protea*. It is favored by warm (25° to 28°C.) temperatures and leaf wetness during infection and can be identified by canker and lesions with red halos (4).
2. *Batcheloromyces proteae* is found on ecotypes of *Protea cynaroides* and little is known about its control and life cycle. The red spots are very evident on the plants' dark green leaves (4).
3. *Dreschlera* spp. are active in *Leucospermum* spp. plants and are most active at 20° to 22°C. during a period of leaf wetness. Red halos appear around sunken necrotic tissue on leaves (4).
4. *Elsinoe* spp. are also active on *Leucospermum* spp. plants. They are scab infections and are similar in appearance to citrus scab; infection again occurs during moist conditions. The corky tissue appears on both leaf and stem (4).

Good hygiene is certainly a contributor to success. Plants that do have foliar problems or seem unhealthy are removed from the nursery and destroyed.

CULTURAL APPLICATIONS

Many cultural applicatons have been discussed previously but the following reiterates some of the most important:

We moisten the media completely and thoroughly, allow the media to drain of all free water prior to the next irrigation. We water in the morning, minimizing overhead application. The plants are adapted to full sun by exposing them from the shade cloth area into full sun during periods of less intense solar conditions.

A site selection for Protea operation should incorporate good wind movement, a minimum of frost below 3°C., and soils that are free draining. Water quality should be good, low in lime and salts.

Many cultivars grow in coastal areas, while others grow inland and may consistently have summer temperatures above 30°C. Coastal cultivars generally do not do well inland and vice versa, though a few adaptable species will survive in both situations. Certain species may have populations in inland areas as well as coastal, upon mountains, and at low altitudes; the propagation and cultural success of species is governed greatly by which population the seed or cutting was selected from.

The selection criteria for propagation is similar to most floral and ornamental crops, although special attention should be paid for the general adaptation of the plant to various conditions; example, "normal garden watering," and higher phosphate soils. New protea cultivars that can tolerate a wide variety of conditions are certainly in demand within the floral and horticultural trades.

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LONG-TERM SHELF-LIFE OF INDOLE-3-BUTYRIC ACID SOLUTIONS

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The use of concentrated indole-3-butyric acid (IBA) solutions is widespread in the nursery industry, however no data is presently available on the shelf-life of these solutions. The purpose of this study was to provide practical information about the effect of storage conditions on the long-term shelf-life of concentrated IBA solutions. The concentration, solvent, and storage environment were chosen to represent conditions that a plant propagator would encounter.

IBA was purchased from two suppliers, United States Biochemical [USB] (Cleveland, Ohio) and Sigma Chemical Co. (St. Louis, Missouri). A bulk quantity of IBA was prepared for each concentration (5,000, 1,000, 0 ppm) and chemical supplier; 50% (v/v) isopropyl alcohol was used as the solvent since it is readily available to the public. The color of freshly prepared solutions depended on the chemical supplier. A 5,000 ppm solution of IBA prepared using the USB product was a light-yellow color. The intensity of this color is proportional to the concentration. The solution (5,000 ppm) prepared from the Sigma product was clear.

The bulk supply for each solution was dispensed (60 ml/bottle) into either clear or amber glass bottles. Two bottles were prepared for each treatment (temperature, bottle color, concentration, and chemical supplier). During the storage period, bottles were located in one of three locations (laboratory shelf, refrigerator, freezer). One series of bottles was stored on an open shelf in a laboratory (72 to 77°F). The laboratory was lighted by conventional fluorescent fixtures. The remaining bottles were stored in the dark in either a refrigerator (43°F) or freezer (32°F). Solutions were analyzed by high pressure liquid chromatography (HPLC) and the mung bean rooting bioassay at the beginning and end of the storage period. HPLC was used as the method for chemical analysis. The rooting bioassay was used to monitor the biological activity of IBA and to detect the presence of inhibitory or promotive compounds that might be produced during storage.

Results indicated that concentrated (5,000 ppm) IBA solutions (USB) can be stored at room temperature in a clear glass bottle for at least 4 months without a significant loss in biological activity of the solutions (Table 1) or breakdown of the compound (Table 2). Results for the 1,000 ppm solutions were similar (data not shown).

Table 1. Effect of 4 months storage on the biological activity of a 5,000 ppm IBA solution.

Storage Conditions		
Bottle color	Temp. (°F)	Mean number of roots per cutting*
clear	72–77	84
amber	72–77	83
clear	43	90
clear	32	83
—control, fresh—		79

*Means of 30 mung bean cuttings, all of which rooted. Means are not significantly different. LSD (p = 0.05) = 11.3

Table 2. Percent of 5,000 ppm IBA remaining after storage.

Storage Conditions		Length of storage (mo)	
Bottle color	Temp. (°F)	4	6
clear	72–77	102%*	102%*
amber	72–77	106	106
clear	43	102	109
clear	32	110	110

*Accuracy of the HPLC method (dilution and analysis) is ±6%

The inability to detect any significant loss in biological activity or breakdown of the product was rather surprising because solutions stored at room temperature had changed from the initial light-yellow, to a bronze color. Exposure to low light does not appear to influence color production as solutions stored in a clear or amber bottle were identical in color. Presumably the color could be a result of a highly colored breakdown product(s) of IBA. The product(s) would be produced in very small quantities since no significant amount of breakdown could be detected (Table 2). The color could also be produced by a contaminant that has no influence on the biological activity of a concentrated IBA solution (Table 1).

The development of the colored product(s) was influenced by temperature. A significant change in color occurred in solutions stored at room temperature, while only a slight change in color occurred in refrigerated solutions. Solutions stored in a freezer maintained their original color. No difference in biological activity or amount of breakdown was detected between the Sigma and USB products stored at room temperature (data not shown) even though the color of the original solutions was different. Color of the Sigma and USB solutions was essentially identical by the end of the storage period.

Analysis of solutions after an additional 2 months of storage at room temperature (6 months total storage) indicated no significant loss in biological activity of the solutions (data not shown) or breakdown of the compound (Table 2). A significant breakdown of IBA was measured after IBA had been stored at room temperature for 19 months.

It is important to note that this study focused on the storage of concentrated IBA solutions in glass bottles. Therefore, these results may not apply to storage in plastic containers or to the potassium salt of IBA (K-IBA). Because the solvent for the potassium salt would usually be water, bacterial growth might be a problem in stored aqueous solutions. Whether the shelf-life of the salt would be similar if it were dissolved in alcohol is not known.

Based on personal observation, extended storage of concentrated alcohol solutions of IBA does result in a discoloration of the inside surface of white or clear plastic bottles. Whether IBA is being absorbed into the plastic is not known.

VOICE: Ralph, where is the Parafilm available that you use in your budding and grafting?

RALPH MOORE: This can be obtained from any medical supply house.

VOICE: In using an IBA solution, where evaporation of the alcohol can occur, does this not change the concentration of the IBA solution?

JAMES ROBBINS: We did not deal with this situation in our studies, but I suspect the IBA concentration would increase as more and more alcohol evaporates during the use of the material.

VOICE: What are the proper storage conditions for the IBA crystals?

JAMES ROBBINS: The chemical supply houses recommend on the bottles the proper storage conditions. I believe they recommend storage in a refrigerator for IBA—and for IAA, storage in a freezer.

IMPROVEMENT OF CUTTING QUALITY BY 4-CHLORORESORCINOL

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AND GAD FRIEDMAN*

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Israel

Abstract. Rooting, in cuttings of several plant species, was promoted by 4-chlororesorcinol, a polyphenol oxidase inhibitor, that was applied at mM concentrations before rooting. The subsequent growth of the cutting was also affected by the treatment with 4-chlororesorcinol. Treated cuttings developed greater number of leaves, larger leaves, and produced an overall greater fresh and dry weight. The treatment inhibited, in *Pelargonium peltatum* L'Hér cuttings, flowering during the rooting period. The treatment also inhibited the activity of polyphenol oxidase in the root initiation region of cuttings. The enhanced vegetative growth is attributed to the more developed root system.

REVIEW OF LITERATURE

Rooting of cuttings is still the most common method of vegetative plant propagation. In many instances, the effect of auxin on rooting is enhanced by the addition of phenolics (6). It was suggested that the phenolics affect activity of oxidases, thus elevating auxin concentration in the cuttings. The involvement of the enzyme polyphenol oxidase (PPO) in the rooting process was proposed by Haissig (4). This hypothesis was supported by observations that described correlations between the ease of rooting of woody cuttings and the enzyme's activity (1) and correlations between the location of the enzymatic activity and the tissues that differentiate into roots (1,8). In the present work 4-chlororesorcinol (4-CR), a specific PPO inhibitor (9), was used to study its effect on rooting of several laboratory and commercial species.

MATERIALS AND METHODS

Cuttings of geranium (*Pelargonium peltatum* L'Hér and *P. zonale* L.), silverberry (*Elaeagnus pungens* Thunb. *B.*), and *Tamarix aphylla* (L.) Karst. (Syn. *T. articulata*) were collected from mother plants, grown slightly shaded, at Gillat JNF Nursery. Cuttings of *P. graveolens* L'Hér were prepared from slightly shaded mother plants in the Faculty of Agriculture, Rehovot. Rooting experiments were carried out on location. Plant material was chosen for maximal uniformity according to height and leaf size. Treatments with various concentrations of 4-CR were given to groups of 20 to 35 cuttings for 2 hours. Subsequently, IBA was given to groups of 20 to 35 cuttings for 2 hours. Subsequently, IBA was given as 0.3% powder

*Gillat JNF Nursery, Northern Negev, Israel

(Hormoril T3) to all the cuttings, except for silverberry; that was given 0.8% IBA. The cuttings were then transferred to peat:styrofoam (1:1) and grown unshaded under intermittent mist for 2 to 5 weeks at a 22°C substrate temperature. Cuttings of bean (*Phaseolus vulgaris* L.) and mung bean (*Vigna radiata* Wilcz) were prepared from 7 and 9 day old seedlings grown in growth chambers under white light (80 μ einsteins m^{-2} sec^{-1}) at 25°C. The cuttings were dip-treated for 24 hr. in 2ppm IBA and various concentrations of 4-CR.

The number of roots per cuttings, or the size of the root system, and the extent of flowering were determined at the end of the rooting period. The criterion in some cases was the size of the root system, rather than the actual number of roots, because roots could not be separated satisfactorily from the rooting medium. Polyphenol oxidase activity in mung bean cuttings was measured after extraction. Extracts were dialyzed overnight to see whether the inhibition could be reversed.

Rooted cuttings were transferred for further growth into 1.5 litre soil-filled polyethylene bags and were grown for 10 to 12 weeks. At the end of the growing period the crop yield was estimated measuring: 1) the number of leaves produced, 2) the size of the mature leaf, 3) leaf or shoot fresh weight, and 4) leaf or shoot dry weight. Each experiment was carried out three times and the data were analyzed using Duncan's multiple range test.

RESULTS

The Effect of 4-CR on the Extent of Rooting

Treating freshly-prepared cuttings with 4-CR caused the formation of more adventitious roots (Table 1) and a better developed root system (Table 2, Figure 1). The treatment with 4-CR also promoted in *P. peltatum* L'Hér, at higher frequency, the appearance of roots above the cutting surface (Table 1), which is the normal rooting zone in geranium. In tamarix formation of lateral roots on the adventitious roots was enhanced by 4-CR rather than the number of roots. Rooting percentage was not affected by the treatment. Only in the case of the silverberry rooting percentage increased with 4-CR treatment from 10 to 30% out of the rooting season and from 50 to 80% in season. *P. peltatum* L'Hér cuttings treated with 4-CR flowered less frequently than untreated cuttings (Table 1). Cuttings of bean (Figure 2) and mung bean formed significantly more roots upon treatment with 4-CR. In the rooting zone the measurable activity of PPO decreased after treatment with 4-CR (Table 3). The inhibition of PPO activity was not reversed by dialysis.

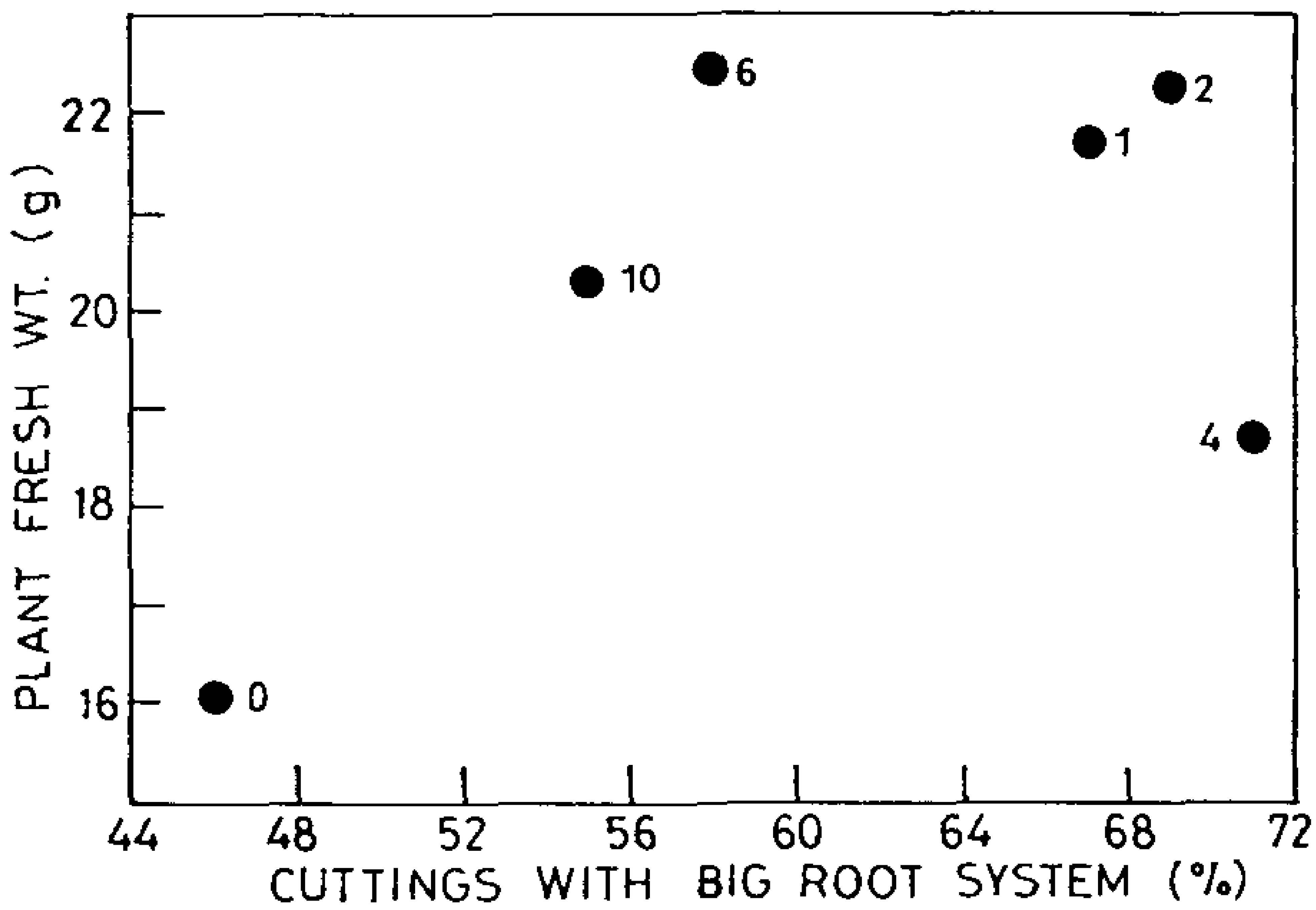

Figure 1. The effect of 4-CR on rooting and vegetative growth of *Pelargonium graveolens* L'Hér cuttings. The numbers in the graph indicate mM 4-CR concentrations applied.

Table 1. The effect of 4-CR on the rooting and vegetative growth of *Pelargonium peltatum* L'Hér [1].

4-CR conc.	Roots per cutting	Flowering cuttings	Leaves per plant	Leaf diameter	Leaf fresh weight	Leaf dry weight
0 mM	30.8a	50%	8.7a	43a(mm)	7.3a	0.85a
0.6	39.4ab	32	8.7a	53.8b	8.7a	0.86a
2	43.8b	,28	9.0a	55.8b	10.6a	1.2bc
6	39.6ab	30	11.6b	60.8b	15.7b	1.34c
20	30a	31	8.1	52.1b	8.5a	1.0ab

[1]30 cuttings per treatment.

The Effect of 4-CR on the Quality of the Rooted Cuttings

Cuttings were planted after the extent of rooting had been determined. At the end of a 10 to 12 weeks growth period, the plants were harvested and their crop yield assayed (Table 1, Figure 1). Treated P. *peltatum* L'Hér cuttings developed significantly larger leaves, more leaves, and greater fresh and dry weight (Table 1). The formation of a larger root system in P. *graveolens* L'Hér cuttings enhanced the subsequent vegetative growth as seen by an increase in the plant fresh weight (Figure 1). Treating P. *zonale* L. cuttings with 0.5 to 4 mM 4-CR resulted in the development of more and larger leaves and an overall greater fresh weight (Table 2). The vegetative growth of rooted P. *graveolens* L'Hér and P. *zonale* L. cuttings was consistently greater in 4-CR-treated cuttings, although not always statistically significant.

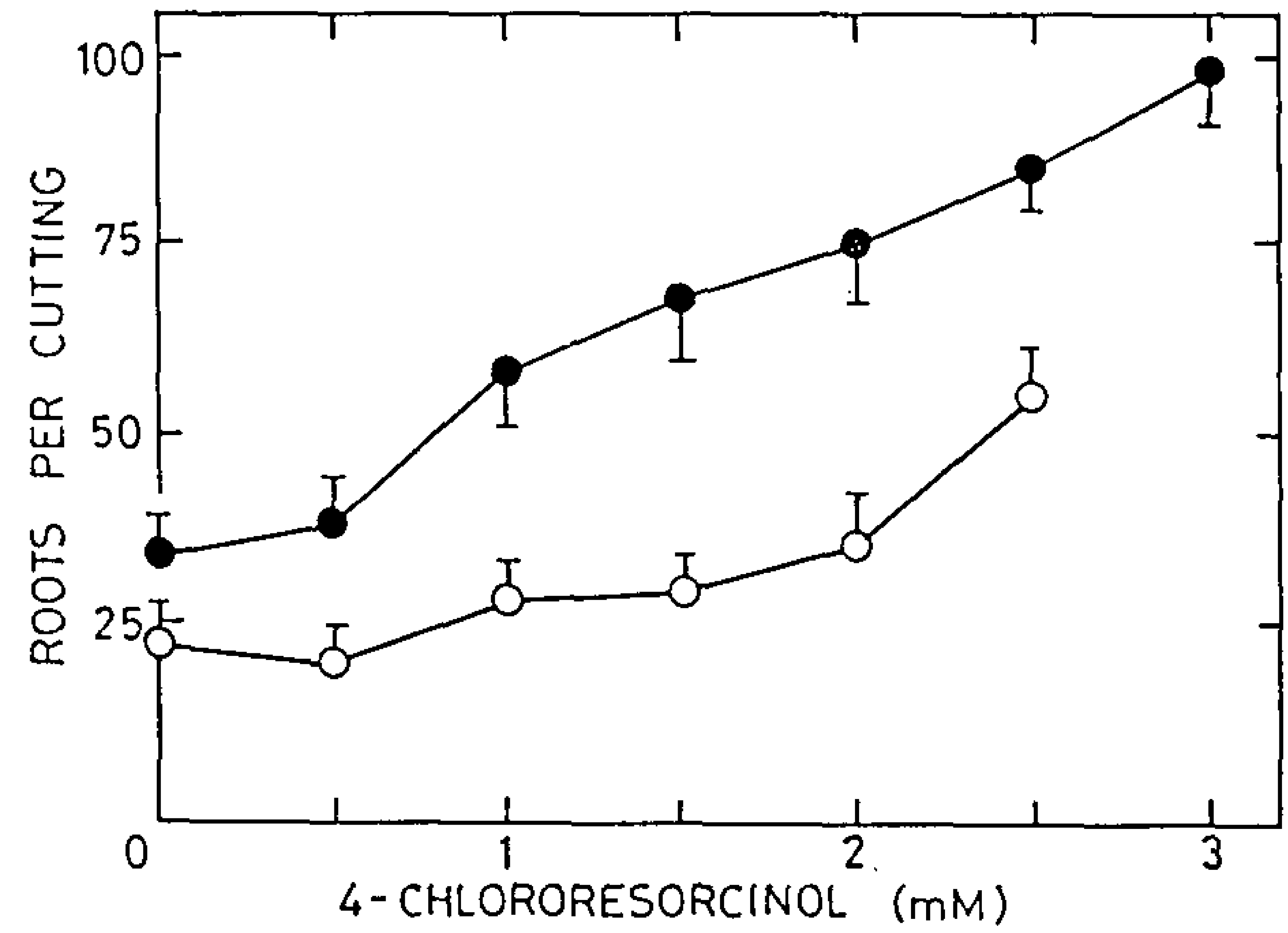

Figure 2. The effect of 4-CR on cuttings of *Phaseolus vulgarus*. Cuttings were dip-treated for 24 hours in various 4-CR concentrations, with (●) or without (○) 2 ppm IBA. The number of roots was counted after 7 days.

Table 2. The effect of 4-CR on the rooting and subsequent vegetative growth of *Pelargonium zonale* L[1].

4-CR concentration	Cuttings with a large root system (percent)	Fresh weight of cutting
0 mM	56	26 ± 11
2	78	33 ± 12
4	70	29 ± 12
10	40	20 ± 10

[1]29 cuttings per treatment.

DISCUSSION

The effect of 4-CR is probably related to its inhibition of polyphenol oxidase (9), which is the only biological activity, so far, attributed to this compound. The plant enzyme was strongly affected by 4-CR. However, we cannot exclude the possibility that it exerted its effect in another way, similar to other phenolics, probably, by inhibiting oxidation of auxin (6).

Table 3. Inhibition of polyphenol oxidase activity in mung bean cuttings by 4-CR[1].

4-CR concentration	Specific/Activity A(410) mg protein^{-1} min^{-1}	Percent inhibition
O mM	1.42a	—
O + dialysis	1.51a	—
1	0.42b	75
3	0.29b	80
10	0.21b	85
10 + dialysis	0.25b	84

[1]average of 3 experiments.

The improved vegetative growth and the inhibition of flowering can be explained by the formation of a more developed root system. Richards (12, 13) described the inhibition of vegetative growth by pruning and the promotory effects of cytokinin sprays on the vegetative growth of fruit trees. Treatment with cytokinins promoted branching and thus vegetative growth of geranium (2). The inhibition of flowering during the rooting period and the first growing stage is desired. Flowers, being a strong sink, hinder the plant from developing an appreciable size at a fast rate. By producing greater amounts of cytokinins, a larger root system can also inhibit flowering (10). The appearance of roots outside the normal rooting zone, i.e. above the cut, also improves the quality of the cutting since the formation of a condensed root system is avoided.

In conclusion, 4-CR promoted formation of adventitious roots and improved the subsequent vegetative growth of cuttings. The ability to obtain a bigger plant in a given time implies that plants may be kept less time in the nursery.

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ALTERNATIVE MEDIA FOR AIR LAYERING[1]

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Sphagnum moss has been the traditional medium used in air layering. Its desirable traits are a good water-holding capacity, good aeration characteristics, and a low capability to carry diseases. The difficulty of handling, wrapping, and tying a handful of wet moss make it a less than efficient system for mass production. Using a 1 in. bark ring girdle and sphagnum moss with either aluminum foil or plastic film required 3 to 3½ min., respectively, to apply an air layer (1). In addition, the cost of sphagnum moss is increasing and this, coupled with the cost of labor to produce an air layer, suggests a need to evaluate some alternative media and systems of air layer production.

Plant propagation classes at the University of Hawaii have experimented with different media as alternatives to the use of sphagnum moss. In addition, some new technologies have created potentially interesting materials which require evaluation.

One of the early substitute substances was called "Red Moss." It was a shredded form of the inner, fibrous redwood bark. It dried out faster than did sphagnum but was nearly as satisfactory as sphagnum for fast-rooting species. Red Moss was more difficult to separate to obtain a good handful, and the difficulties in applying it were the same as for sphagnum. It did not remain in our market too long, however.

The most successful alternative was the use of an expanded peat plug, the Jiffy 7. Once wet and expanded to full size, it was sliced part way through and placed around the girdled stem. Water retention was good and rooting was satisfactory, but the small volume of the peat plug was a limitation to development of a large root mass. The time spent in making the girdle, applying the slashed peat plug, and wrapping with aluminum foil was just under 2 minutes (1), a much more efficient operation than with sphagnum moss. A larger plug would be desirable, but the cost factor must be considered as well.

Castle and Cooke's Techniculture, Inc., in Salinas, California, developed a small peat plug bound with a rubbery space-age polymer for the rooting of cuttings. A sample was made for us to try out for air layering. It held water well, had a good volume for root development, and was easily handled and wrapped with foil. Rooting was satisfactory. The cost of a large plug may be un-

[1] Poster presentation

economic, but on high value layers such approaches may have an advantage.

The phenolic foam blocks used for propagation also offer potential for use as easy-to-use air layer units. The present size of foam propagation blocks presents the same small volume disadvantage as peat plugs, but large sheets 2" thick may be carved to form blocks of suitable size and a central cavity is easily carved out.

Rockwool has been available for over 15 years and has found extensive use in propagation and culture of horticultural crops. It is offered in blocks of different size as well as larger slabs which can be cut to desired size. Water is readily taken up, but the wet weight of a saturated block may be too great and some draining must be allowed. A slice to the middle of the block permits its application to the girdled portion of a branch, and it is easily handled and wrapped as a single unit.

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1. Myers, D. and R. A. Criley. 1980. Various cuts, media, and wrapping material used in air layering of *Schefflera arboricola*. *Hort-Digest* 56:5–7.

A NEW, EFFICIENT METHOD FOR EVALUATING ROOT GROWTH POTENTIAL OF PLANTING STOCK USING A ROOT AREA INDEX[1]

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Root growth potential (RGP), the ability of seedlings to promptly and abundantly initiate and elongate new roots after transplanting, is an important and useful attribute of planting stock performance. However, it is generally laborious, tedious, and subjective to measure. A method was developed that employs aeroponic culture of seedlings in a root mist chamber (RMC) and measurement of root growth by changes in root area index (RAI) with a video camera and digitizing area measurement system. The

[1] Poster Presentation
[2] Research Plant Physiologist
[3] Supervisory Plant Physiologist

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area meter scans each horizontal TV line and sums the segments that are traversed by roots. A high resolution camera was used for accurate area measurement of roots. The method consists of: 1) premeasuring RAI of individual seedlings, 2) growing seedlings in the RMC for about 2 weeks (depending on species), 3) staining new roots to make them visible to the camera, and 4) remeasuring RAI of individual seedlings.

An experiment was conducted to compare xylem water potential (XWP) of seedlings grown in the RMC with that of seedlings grown in pots of a growing medium and seedlings grown in hydroponic culture. XWP, measured with a pressure chamber, of seedlings grown in the RMC was similar to that in potted seedlings, and increased (became less negative) when new roots were initiated. Seedlings in the RMC initiated new roots 1 week sooner than potted seedlings. XWP in hydroponically grown seedlings steadily decreased and very few new roots were present after 20 days.

A second experiment determined the relationship between root growth quantified by difference in RAI and that quantified by direct measurement of new root number and length. A range in RGP was accomplished by placing groups of 10 jack pine 2-0 seedlings in a forced-air oven (40°C, 30% RH) for 0, 10, 20, 30, and 40 min., then growing them in the RMC for 17 days. Root growth of individual seedlings was evaluated by the RAI method and by counting and visually estimating length of all new roots > 0.5 cm. Linear regression of individual seedling data revealed r^2 values of 0.88 and 0.90 for predicting number of new roots and length of new roots, respectively, from difference in RAI. Eleven seedlings/person/hr were completed using the visual estimation method compared to 32 seedlings/person/hr using the RAI method.

The research documents the accuracy and productivity of the RAI method. Observer subjectivity is nearly eliminated.

OBSERVATIONS ON WATERING CONTAINER-GROWN CITRUS

JEREMY M. TOLLEY[1]

Tolley's Nurseries Pty. Ltd.
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This report is based on observations made in our citrus nursery, where the media, containers, and nursery methods differ very little from other nurseries. The major difference is that the crop is for orchard rather than ornamental planting.

Our citrus plants take from 9 to 10 months to develop and most of the trees are sold within 24 months. Seasons are important to the orchardists who plant the trees.

The medium used in our propagation is 80% eucalyptus hardwood sawdust and 20% sand, plus Nutricote and other nutrients required for normal plant growth. Containers are both overhead and hand-watered.

The Problem. A problem developed in our production so that trees were not meeting our sales schedule. There was no lack of bud burst, but there was a following lack of shoot length and development.

Often 3 or 4 leaves would shoot out from a bud, and one month later these leaves would begin to show chlorosis and nutritional disorders, often followed by tip abortion and senescence for long periods of time, even over the summer growing period. The fact that older plants in the same house had dinner-plate leaves that were dark green tended to suggest that the medium and its nutrient status were not to blame.

It was not a question of dead trees, or trees not acceptable for sale, but rather the trees were slow to reach their minimum saleable height, thus taking up valuable nursery space and reducing cash flow.

Seedling stocks were checked and their vigour observed, and the budwood was checked without finding any clues. It, therefore,

[1] Jeremy Tolley, Nursery Manager of Tolley's Nurseries Pty.Ltd., was killed in a car accident on Friday, 10th April, 1987 aged 26.

He was a born propagator, and in his own garden and shadehouse took a keen interest in all types of plants and flowers. His professional field was citrus propagation and horticultural management planning.

He attended Cal Poly University at San Luis Obispo, California, in Ornamental Horticulture, until forced by illness to return to Australia. On recovery three years later he joined his parents in the family company as Nursery Manager, handling his section with his own innovative flair.

He was a keen sportsman, and was Riverland Solo Speedway Champion. He also was a "Golden Gloves" boxing champion.

He attended IPPS meetings in California and Hawaii, after becoming a member, and gave his first address in Adelaide in 1986.

appeared that these problems were being caused by another of our nursery practices.

The Solution. In an attempt to solve the problem, some of the trees were put in a separate area during early summer, and signs were erected saying, "DON'T WATER."

In the month following this treatment, re-greening of the leaves occurred, and later buds on both rootstock and scion commenced growth. The resultant shoots were of good caliper and length. Some of the original trees were kept as controls, the only difference between the two groups being watering practices.

The normal practice in a saline water area is to have a free draining mix to facilitate leaching. These words, "free draining," were most of our problem. The mix had a high porosity, and a large air volume.

Our normal watering practice to leach out salts was to put on sufficient water to ensure run-off out of the bottom of the pot. My findings were that after such a watering event the pot remained about 80% saturated for up to 60 hours. This meant that most of the volume of the mix had no oxygen, other than dissolved oxygen for the roots.

Proof of this was the level of root destruction. Most well-developed container plants have roots at the bottom, at the surface, and some roots evenly distributed throughout the container. In our containers all the bottom roots were rotted off and there were only roots in the top 3 or 4 inches. This area drained gravitationally more quickly.

The total amount of water available to the plant in the four litre bags filled with our mix was one litre just after watering. It is still one litre a week later if the plant is not using it. The evaporation rate of water from the surface of a pot in a polyhouse is very small.

We now water every 10 to 14 days even in temperatures of 30 to 40°C. Our nursery watering schedule is on a minimum replacement basis with pH and EC changes being the only cause for saturation watering.

I have found a relationship among high frequency watering, the amount of root caliper, and the long wet/dry cycle. The roots of frequently watered plants tend to be fine and web-like, rather than the thick, corky roots of plants grown in the field, and by the wet/dry cycle watering. I have no quantitative data on this other than my observations of the root systems of nursery and field-planted stock, but I am sure that it is important in growing good, healthy container plants.

The intelligent application and management of water has improved plant growth, saved time, and increased profitability in our nursery.

PROPAGATION OF *BREYNIA DISTICHA* 'ROSEO-PICTA' BY HARDWOOD CUTTINGS

VIC FINES

Christmas Bush Nursery
Nelsons Bay, New South Wales

Breynia disticha 'Roseo-picta' [syn. *B. nivosa* 'Roseo-picta'] (Euphorbiaceae) is a delightful ornamental plant of uncommon beauty. Exotica describes it as a most unusual plant having small oval papery leaves that are mottled or variegated, green white and pink, looking like flowers, with red stems and petioles.

This plant has proved difficult to propagate in the past, so we have developed the following method for its propagation.

Squat pots (175mm) are used for the propagation of the cuttings. A layer of charcoal about one centimeter in depth is placed in the bottom of the pots, and a 15mm layer of perlite is placed on top of this. A 75mm pot is placed in the centre of the larger pot on the perlite. The larger pot is then filled with a propagating medium of 2 parts sterilised coarse river sand, 2 parts perlite, and 1 part vermiculite. The small centre pot is then three quarters filled with sterile river sand (Figure 1).

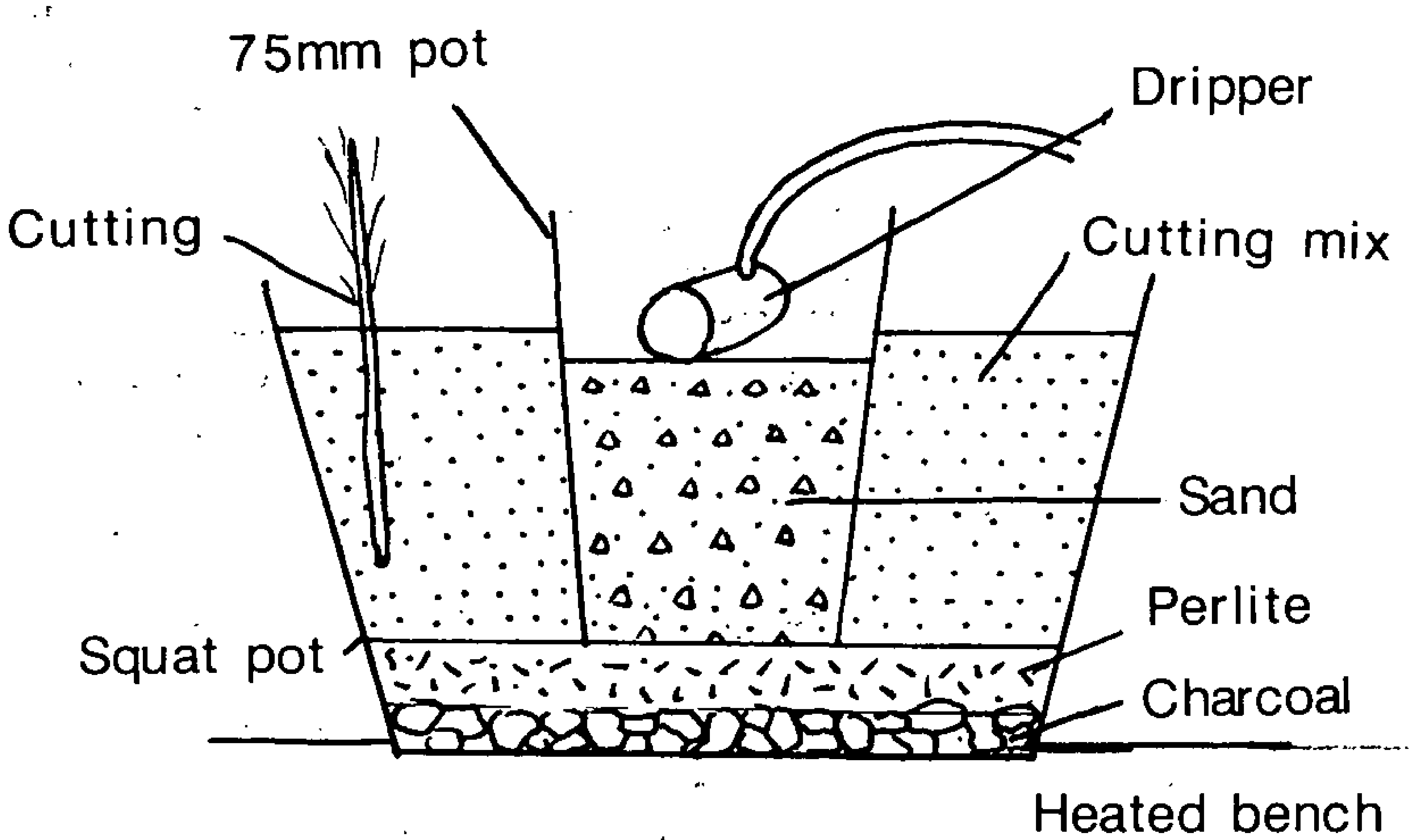

Figure 1. Squat Pot with small centre pot and dripper set up.

All the sand is sterilised in a commercial Sharp microwave oven. An alternative method is to prepare the pots of medium and sterilise the mix and the pots together.

The microwave oven holds four units at a time. They are heated for 12 minutes to a maximum temperature of 100°C. This type of sterilising is economical, especially for a small operation.

The pots are set out on a heated bench and Moss® drippers (5 litres per hour) are placed, one per pot, in the small centre pot. It is easier to insert the drippers before the cuttings have been inserted in the pots.

The cuttings are taken in mid-summer (January)—this is very important. Three node cuttings are used. First they are washed with Clensel®, a detergent type garden insecticide. Active ingredients are: oil of citronella, 11g/l, ammonia, 4.5g/l, potassium citrate, 118g/l, at a rate of 40mls per litre, to remove eggs spores and other possible contaminants. The cuttings are then wounded and quick-dipped in a 10,000 ppm IBA solution.

The cuttings are then inserted 35 to 45mm into the sterile medium in the large pots, and watered with a Previcur® solution (1.5 mls per litre).

The heated bench is then covered with a plastic tent. NO MIST IS USED.

On the third day after the cuttings have been set, the drippers are turned on and set to operate for 2 minutes every second day. This is usually enough to keep the medium slightly moist and the humidity in the tent at a satisfactory level for this time of the year. However, we monitor the moisture content in the pots by placing, and leaving, a thin wooden stake in one of the pots. This is checked every day, and if the stake dries out more water is added. This is a necessary safeguard as the heated bench tends to dry things out from the bottom up.

After three weeks the cuttings are watered with an all-purpose liquid fertiliser (Trygon Field Pack® at 4mls per litre).

After four weeks the cuttings have usually rooted and are removed from the heated bench to the shade house. We continue to fertilise them weekly with the liquid fertiliser solution. At ten weeks they are potted-on into 150mm pots.

The dripper and humidity tent system has been successfully used by our nursery for *Bougainvillea, Hibiscus, Pyrostegia, Acalypha,* and other plants where constant misting tends to cause fungal problems.

USE OF DIATOMITE AS A SUPPLEMENT TO GROWING MEDIA FOR ORNAMENTAL PLANTS

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The desire to produce uniformly standard potting media is a major reason for the evolution of soilless mixes. Components such as peat, sand, composted sawdust, pine bark, vermiculite, and others are used worldwide but others are only used locally because of specific availability. The possibility of using diatomite arose because of sizeable deposits of this material at Barraba in north-eastern New South Wales.

Properties of a diatomite. Diatomite is a sedimentary rock which consists of siliceous skeletal remains of tiny freshwater or marine organisms called diatoms. The microscopic organisms measured only a few microns in length and when they died the skeletons sank to the bottom of the sea or freshwater lake where very thick deposits gradually accumulated. Geological movements of the earth's crust have relocated the deposits into accessible situations from which the diatomite can be mined. The New South Wales deposit was laid down in a freshwater lake and is rich in a diatom known as *Melosira granulata* which had skeletons with an average length of 15 microns. The deposits are up to 100 million years old. Diatom skeletons alone are very clean but often the deposits of diatomite also contain clay particles which influence the properties of the mined product. A typical analysis of the diatomite as mined, processed, and used in growing media is shown in Table 1.

Table 1. Composition of horticultural grade diatomite.

Chemical composition	Range (%)
SiO_2	65–85
Al_2O_3	14–18
Fe_2O_3	3.0–4.0
TiO_2	0.65–0.85
P_2O_5	0.04–0.08
MnO	0.04–0.06
CaO	1.6–2.2
K_2O	0.9–1.2
pH	8.0 (average)
Physical properties:	
Apparent density	0.04–0.05 g. per ml.
Water absorption	50–130% by weight

The diatomite used in these trials was very absorbent, chemically inert, light weight, and contained sufficient clay to provide very useful cation exchange capacity (CEC). Since the

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diatomite formed in fresh water there was no risk of salt contamination in the material.

The 5.0m. thick deposit of diatomite at Barraba is covered by an average of 3.0m. of overburden and 0.5m. of topsoil. The trials described below compared the performance of the material as mined (raw ore fines) with calcined material produced by passing the raw ore fines through a coal-fired rotary kiln. During the calcining process, water is driven off, any organic matter is burnt off, and the silicon dioxide is changed from an amorphous to a crystalline form.

In the literature there have been brief references to the use of diatomite in growing media but variation in pH among batches, cost, and contamination with sodium chloride are cited as possible problems.

Trials with seedling mixes. Peat, vermiculite, and two grades of diatomite were used to prepare mixes in which tomato and onion seedlings and marigolds (as a flowering pot plant), were grown. The composition and properties of the mixes are shown in Table 2.

Table 2. Composition and properties of seedling/pot plant mixes.

Mix	Composition (% by volume)				Properties	
	peat	vermiculite	diatomite (r.o.f.)	diatomite (calc.)	pH	E.c. (μScm^{-1})
A	50	50	0	0	4.7	23.8
B	0	50	50	0	8.1	26.2
C	50	0	50	0	5.5	35.0
D	25	50	25	0	6.6	24.0
E	25	25	50	0	5.3	37.5
H	0	50	0	50	9.3	42.0
I	50	0	0	50	7.9	32.5
J	25	50	0	25	7.2	19.7
K	25	25	0	50	6.7	22.5
L	50	25	0	25	5.7	28.0

Tomatoes (cv. Rouge de Marmande) and onions (cv. Hunter River Brown) were used in the seedling trial. With each of the eleven mixes, 3 seedling punnets were sown with tomatoes and three with onions; 25 tomato seeds or 40 onion seeds were sown in each punnet. The seeds were covered uniformly with a thin layer of the appropriate mix and all punnets were watered with a fine spray. The punnets were kept in a fibreglass greenhouse throughout the trial.

The number of emerged seedlings was counted regularly and the results are shown in Figures 1 and 2.

Trials with mixes for a flowering pot plant. A dwarf marigold (cv. Janie) was used because of its rapid growth. Seed was sown into a 50:50, peat:vermiculite mix, with the seedlings transferred to the trial mixes in 140mm diameter pots 14 days later.

The eleven mixes shown in Table 2 were used but with Nutricote and Micromax added to provide slow-release nutrients,

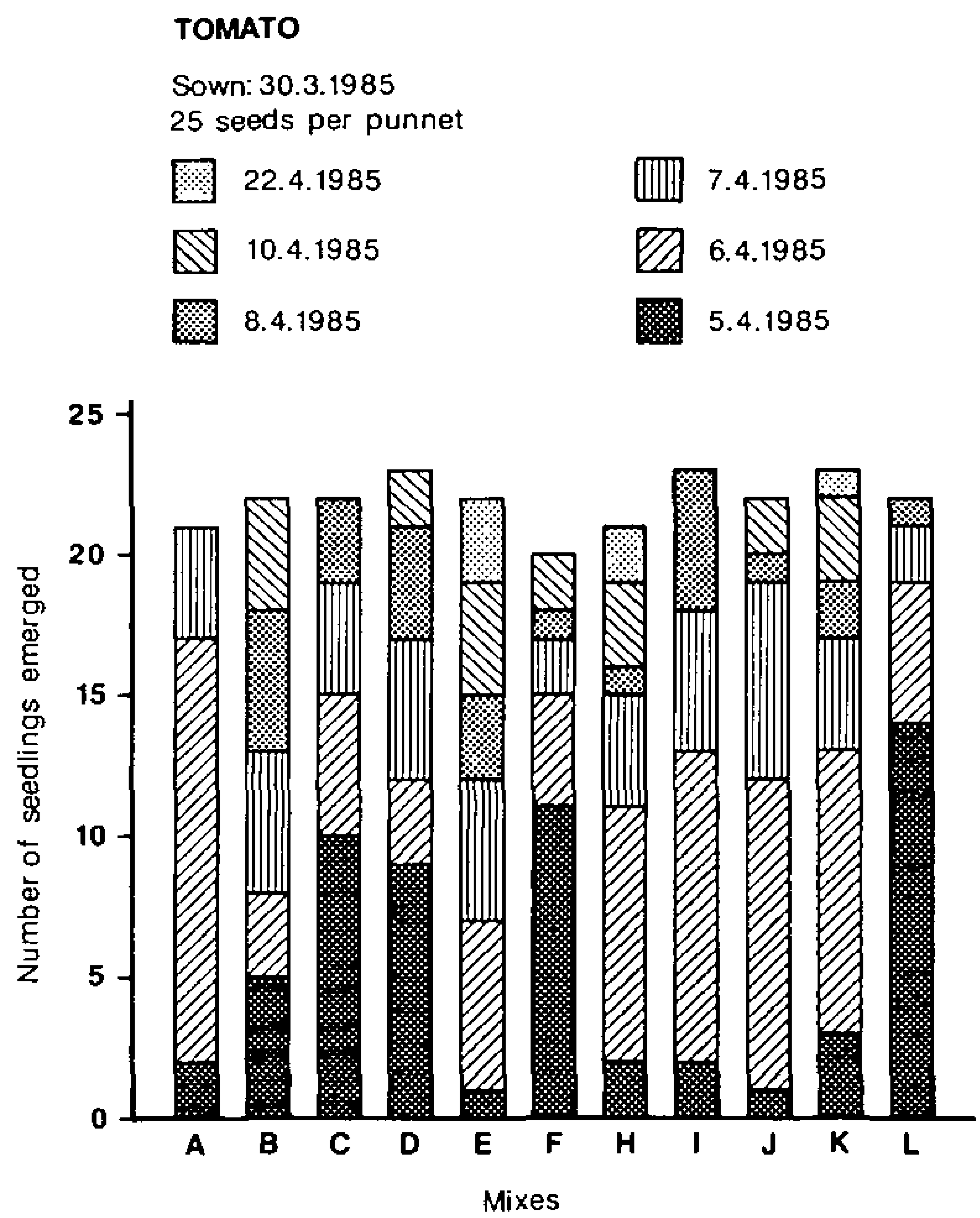

Figure 1. Emergence of tomato seedlings cv. Rouge de Marmande after sowing in a range of mixes.

Table 3. Composition of commercial mixes.

Mix 1		*Mix 2*	
Ingredient	*Quantity*	*Ingredient*	*Quantity*
Composted hardwood sawdust	30%	Composted hardwood sawdust	25%
Composted bark fines	30%	Composted softwood sawdust	15%
Coarse sand (double washed)	20%	Composted bark fines	25%
Composted horticultural bark	10%	Coarse sand	20%
Black soil	10%	Killarney® peat	15%
	per m³ of mix		per m³ of mix
4–5 month Nutricote	2kg	3–4 month Osmocote	1kg
8–9 month Nutricote	2kg	8–9 month Osmocote	2.5kg
Coated iron	500g	Micromax	500g
Micromax	500g		
IBDU	300g		
dolomite lime	1kg		

and with calcium carbonate added to raise the pH. One seedling was potted into each 140mm pot and 30 pots of each mix were used. The

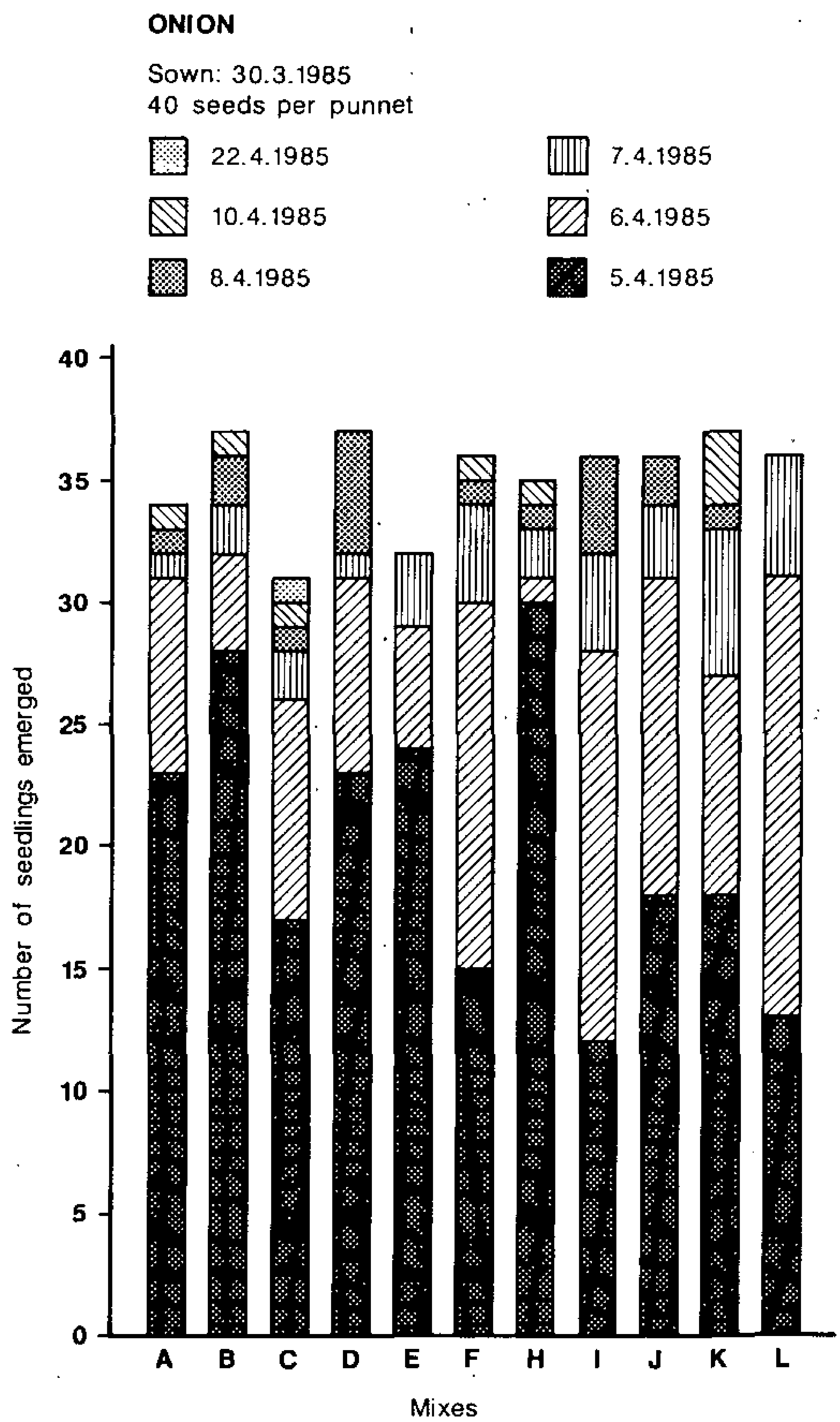

Figure 2. Emergence of onion seedlings cv. Hunter River Brown after sowing in a range of mixes.

plants were grown in an unheated greenhouse throughout the trial. Three weeks after potting the 30 plants in each mix were divided into two groups of 15. One group in each mix was liquid-fed regularly with the proprietary material, Thrive, during the remainder of the trial while the other group was given water only.

The trial was terminated 10½ weeks from potting, at which time the aerial parts of each plant were oven-dried and the dry weights recorded. The results are shown in Figure 3.

Trials with mixes for Australian native plants. Four Australian native plants were used in this trial—*Callistemon* 'Kings Park Special', *Melaleuca armillaris, Grevillea* 'Ivanhoe' and *Grevillea obtusifolia*. Two commercial potting mixes were used, supplemented with different rates of diatomite. The physical ingredients and nutrient status of the commercial mixes is shown in Table 3.

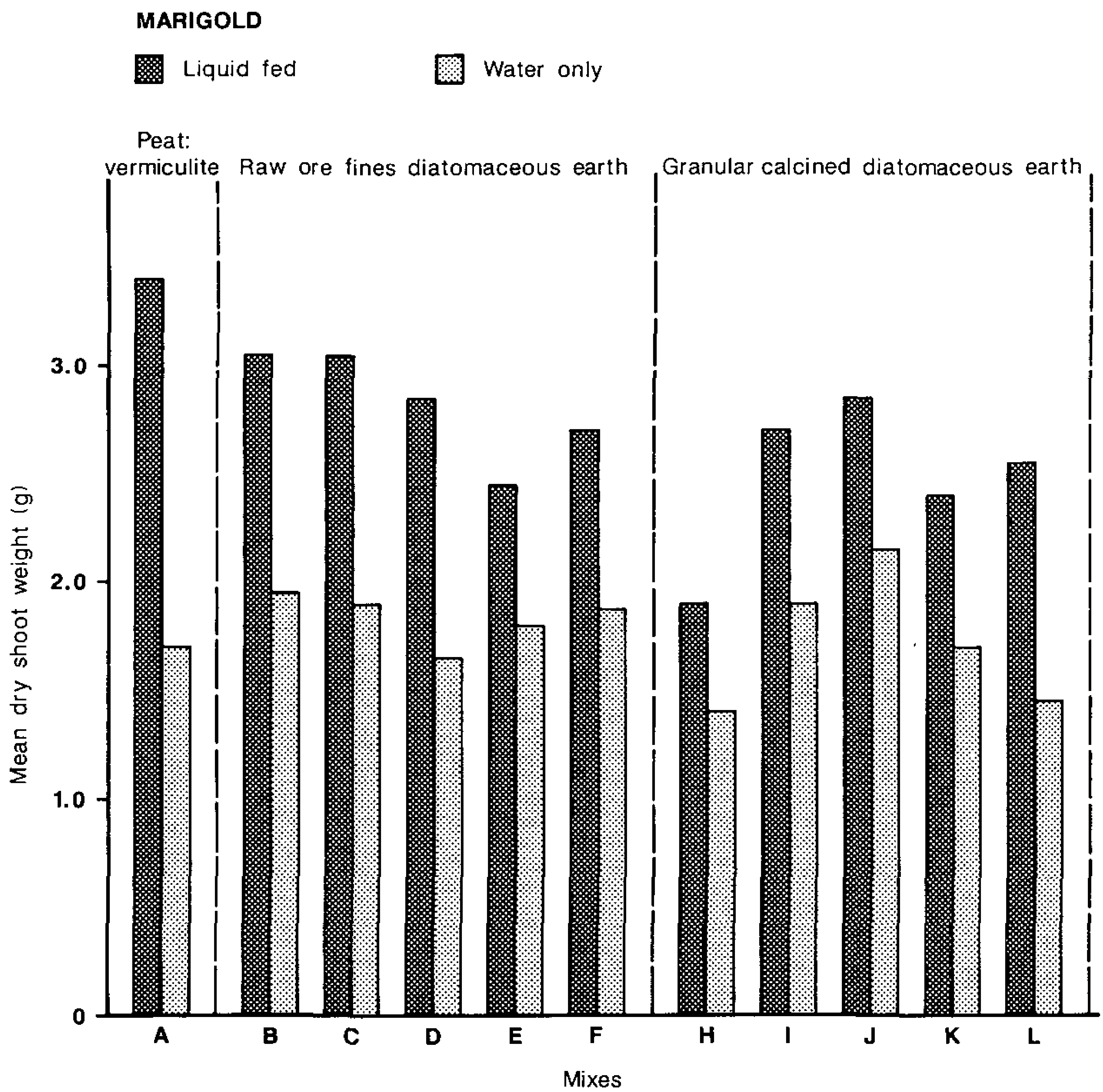

Figure 3. Mean dry weights of marigolds grown in a range of mixes with diatomaceous earth.

Raw ore fines and calcined diatomite were mixed with the commercial mixes in the proportions shown in Table 4 which also shows the pH and electrical conductivity of each mix.

Rooted cuttings of each test species were selected by the author at a large local propagation nursery. The rooted cuttings were potted up into tubes and grown on prior to potting into 150mm diameter, 1.5 litre growing pots. Plants were rigorously sized-graded prior to final potting in order to provide as uniform material as possible; 12 plants of each of the four Australian natives were potted into each potting mix. The trial was terminated 6 months after the final potting when overall plant heights and dry weights of aerial portions were determined. The results are shown in Table 5 and 6.

CONCLUSIONS

No differences were observed in the emergence and growth of tomato and onion seedlings in a range of mixes containing different

Table 4. Composition and properties of Australian native mixes.

Mix	Composition (% by volume)				Properties	
	Commercial Mix 1	Commercial Mix2	Diatomite (r.o.f.)	Diatomite (calc.)	pH	E.c. (μScm^{-1})
A	100	0	0	0	5.1	1590
B	75	0	25	0	6.8	1200
C	75	0	0	25	6.7	1541
D	50	0	50	0	8.7	755
E	50	0	0	50	7.5	1475
F	0	100	0	0	6.3	1117
G	0	75	25	0	7.4	600
H	0	75	0	25	7.0	997
J	0	50	50	0	8.8	713
K	0	50	0	50	7.6	937

Table 5. Plant height (cm) 6 months after potting.

Species	Mix 1					Mix 2				
	Neat	25% diatomite		50% diatomite		Neat	25% diatomite		50% diatomite	
		(calc)	(rof)	(calc)	(rof)		(calc)	(rof)	(calc)	(rof)
Callistemon 'Kings Park Special'	39.5	62.0	57.0	67.0	49.0	71.0	67.0	60.0	72.0	64.0
Melaleuca armillaris	69.5	95.0	88.0	97.0	84.0	105.5	105.5	97.0	111.0	92.0
Grevillea 'Ivanhoe'	77.0	87.0	79.0	87.0	43.0	87.5	79.0	64.0	86.0	45.0
Grevillea obtusifolia	—	—	—	—	—	—	—	—	—	—

Table 6. Shoot dry weights (g) 6 months after potting.

Species	Mix 1					Mix 2				
	Neat	25% diatomite		50% diatomite		Neat	25% diatomite		50% diatomite	
		(calc)	(rof)	(calc)	(rof)		(calc)	(rof)	(calc)	(rof)
Callistemon 'Kings Park Special'	17.4	33.2	30.1	36.9	28.9	31.2	32.3	24.4	40.2	33.1
Melaleuca armillaris	30.9	51.1	38.0	57.1	42.5	46.3	54.0	42.9	50.4	39.7
Grevillea 'Ivanhoe'	38.4	48.7	42.8	58.6	10.5	41.7	46.8	48.0	49.2	16.3
Grevillea obtusifolia	19.8	25.7	24.0	28.0	25.8	24.0	26.0	21.5	17.5	died

grades of diatomite.

Growth of marigolds was commercially acceptable in all mixes but the best results were obtained in mixes containing the raw ore fines grade. This is thought to be due to the fact that the unprocessed mined diatomite from Barraba, NSW, contains 30 to 40% clay (kaolinite and halloyrite) which provides cation exchange capacity not exhibited by the calcined product.

Most of the Australian native plants grew at least as well in the mixes containing diatomite as in the unsupplemented commercial mixes. The exception was *Grevillea* 'Ivanhoe' which reacted extremely unfavourably in mixes containing 50% of the raw ore fines grade of diatomite. The large, calcined particles remained discrete throughout the trial and improved the drainage and aeration characteristics of mixes. The raw ore fines product with the high clay fraction reduced water infiltration rate, drainage, and aeration.

The variations in growth shown by *Grevillea obtusifolia* demonstrated the need for further work and additional commercial trials are being undertaken to see if preferential patterns can be determined.

Acknowledgements Thanks are due to Australian Diatomite Mining Pty. Ltd. who provided the initiative for these studies, also to Hawkaid (the Research and Development unit of Hawkesbury Agricultural College) who provided valuable administrative assistance.

APPLICATION OF PHOSPHORUS TO PROTEACEOUS PLANTS

ADRIAN BOWDEN

Plantex Australia Pty. Ltd.
62 Thomas St.
South Lake, Western Australia

The basis of this discussion came about indirectly from a statement made by Professor Carl Whitcombe at Oklahoma State University several years ago in which he said "pH doesn't matter." I was reluctant to accept this statement, so over time I set out to find out what he was really saying.

I have concluded that there is some truth in his statement with the following qualifications. There is no problem if the necessary elements can be applied in the correct form to sustain plant growth without becoming fixed, and thus unavailable to the plant. However, for more practical purposes, such as growing commercial quantities of blue-flowering hydrangeas at a pH of 7.5 to 8.0 it is probably much easier and cheaper to achieve good plants at a pH of 5.5 to 6.5.

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Here we had the situation of a university professor questioning one of the traditions of nursery practice.

This suggested to me that everything was open to question and this led to my assault on the claim that plants from the family Proteaceae should not be supplied with phosphorus. This is the current advice tendered by many researchers and extension officers worldwide.

When one thinks about this it is in error. The facts are these (and, in my opinion, facts are the current statement of knowledge that changes over the years so, by definition, they are temporary)—

- plants from the family Proteaceae respond well to phosphorus with much improved growth rates.
- the quantity and rate of release of phosphorus is important.
- the form of phosphorus applied is important.
- the use of the wrong form and the wrong quantity of phosphorus can be most damaging.

A similar effect can be obtained with alcohol on humans. A little can be quite nice, too much causes a hangover, and eventually too much over a long period causes death.

Many researchers have used superphosphate as their source of phosphorus on plants in the family Proteaceae. In containers this causes major problems; however in the field I have observed many cases of banksias responding well to superphosphate applied to wheat fields. These plants however seldom get a high application of fertiliser as they are usually on the fence line and often on the other side of a firebreak, from the area being fertilised for wheat.

Here we have a beneficial effect of superphosphate, when correctly applied, i.e. in low concentration and volume. (It can be toxic when incorrectly applied.)

Another example is the application of phosphorus by liquid feed methods, using low concentrations of 100–150 ppm N, 70 ppm P, 100 ppm K every two weeks. This achieved good growth results with a wide range of plants in the family Proteaceae when grown in containers. The source of phosphorus was mono ammonium phosphate.

We believed that a slow-release form of phosphorus was needed to reliably grow a wide range of these plants. Many forms and concentrations were tried; the most reliable proved to be a Mitsubishi product called IB 10-10-10. We have been using this exclusively for the past five years even though it has 10% phosphorus. It is used on all our Proteaceae plants including *Banksia, Grevillea, Leucodendron, Leucospermum, Protea*, etc.

This product really is slow-release under a wide range of soil types, temperatures, and watering conditions. Many field tests have been carried out in Kuwait where the temperature can be 48°C for several months of the year, and where much irrigation is done with water having a salinity of up to 8000 ppm.

It out-performed other products because the three elements, nitrogen, phosphorus, and potassium are all in slow-release form and stable in their own right. Some are coated with silica or IBDU to slow their rate of release down to the desired level before being combined into a single pellet. The size of these pellets determines the length of the release time.

Technically 10-10-10 is a hardened IB compound, known as IBSI, with 80% of its 10% nitrogen derived from IBDU. IBDU is the only slow-release nitrogen that is slowly and evenly dissolved to a soluble form of nitrogen that can be utilised by plants. Other slow release forms of nitrogen depend on certain temperatures and bacterial activity, adequate coating thickness and technique, and/or diffusion of soluble nitrogen through a porous membrane.

The pellets are very hard and large, from 5 to 10mm in diameter, and composed of IBDU, superphosphate, fused magnesium calcium phosphate, and potassium sulphate. In this case the fused magnesium calcium phosphate and the superphosphate react to form a compound hardening the pellets and suppressing the rate of release of the elements, and making the effectiveness of the pellet to be from 6 to 8 months.

Another product, known as "Woodace", is a briquetted fertiliser containing IBDU, Linstar (a form of slow-release phosphorus), and fused potassium silicate. It has a very long release period of up to 2 to 3 years.

As IBDU, Linstar, and fused potassium silicate are all available as individual fertilisers it is possible to have any combination of slow-release N-P-K you wish. However the time of release of the elements is limited to 3 to 4 months because of the size of the granules. Only by combining all the elements in the one granule can they be made to last up to 3 years.

These fertiliser combinations offer several advantages. They are long-lasting, safe, simple to use, and labour saving. Probably the most important feature of IBDUSI is that there is no wastage due to leaching from overwatering. This is because the product is only slightly soluble in water, and the size of the pellet determines the release pattern. Microbial action breaks down the outer surface of the pellets to start the fertiliser effect.

Sensitive plants, such as azaleas and proteaceous plants, actually use the fertiliser as it is supplied. We have had many instances where 4 or 5 pellets have been placed on the top of a pot and the roots actually penetrate the pellets and hold them. The pots can be turned upside down and they will not fall off. Generally with all other slow-release fertilisers tried, roots tend to stay at least a centimeter away from the source of the nutrient, as the salt concentration is too high for them to approach any closer, let alone penetrate and establish a "cocoon" around the source of the fertiliser.

As well as placing the granules on the soil they can be added to the soil mix with excellent results.

So there we have it—another statement brought into question and found to be incorrectly expressed. What should have been said was: "plants in the family Proteaceae are sensitive to phosphorus when it is applied in the wrong form and the wrong concentration."

When phosphorus is applied in the correct form however, the results are very impressive with much increased growth, good leaf colour, firm stems, better yields of flowers, and more cutting material for propagation per plant.

As always, you will need to adjust these findings to your own production systems and do the necessary trials to verify these claims before achieving the results outlined above.

THE INFLUENCE OF RADIO COMMUNICATION TOWERS ON THE PROPAGATION OF FUCHSIAS

DEBORAH LAW AND R. A. de FOSSARD

Tamborine Mountain Plants
Eagle Heights, Queensland

Tamborine Mountain Plants specializes in fuchsias and these are grown from cuttings. Our main market is for potted plants in flower in the winter months. To feed this market, about 85,000 cuttings are struck in summer, during the months of December and January, each year. The cuttings are struck in 50mm tubes with a propagation mix consisting of peat and perlite, and the tubes are placed, 109 tubes per wire tray, on wire benches in an "open" area, and the cuttings are misted at regular intervals during the day. The "open" area consists of walls of solar-weave and the "roof", made of wire mesh supported by water-pipe, is covered with solar-weave over the newly-struck cuttings and with 50% shade-cloth over older cuttings. The nursery is supplied with bore-water.

In late February, 1986, a rapid deterioration of the fuchsia cuttings occurred, affecting first the stem tips and leaves, then the stem, and much later, the roots. Nearly 80% of all cuttings were affected. The immediate task was to identify the cause of this dieback but, even if it had been readily apparent, already the nursery's main market had been lost because no rapid striking of cuttings could make up for the two months required to reach the same stage of maturity. But the cause was not readily apparent, everything had been done in exactly the same way in 1986 as in previous years; the same propagation mix, the same bore water, the same fertiliser program and so on. Within a fortnight, we were able to rule out a microbial cause, so we knew we had to find a non-microbial

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But what of the zero boron readings in the initial leaf analysis? We were unable to offer any explanation for this and could not find any references to the effect of a boron deficiency on fuchsia cuttings. The bore water contained boron and was the same bore water used in previous years. Was it possible that somehow the high concentrations of zinc within the leaves had inhibited boron uptake and had the boron deficiency killed the cuttings? A computer search of the literature covering over 350,000 citations failed to reveal any studies linking zinc with boron.

We could not explain the boron deficiency but by autumn, we were sufficiently confident that we had suffered a transient phenomenon, to start afresh with new cuttings, albeit far too late to save the nursery from financial problems due to loss of its main market niche. Fresh cuttings were struck and, when they had become established, samples were sent for leaf analysis. The cuttings were not as vigorous as normal but they suffered few signs of die-back, and the leaf analysis revealed adequate levels of boron (about 28 ppm) and a still quite high level of zinc, probably because of the content of zinc in the mother plants.

In early summer of 1986, when a new cycle of propagation had commenced, cuttings of four fuchsia cultivars were selected for two experiments. One experiment involved a hydroponic set-up using very high quality water "free" of boron. Some treatments were without boron as an additive whereas others had 10 ppm as an additive. Although the hydroponic system was not ideal, we can report that none of the cuttings in any of the treatments developed die-back. The second experiment involved misting zinc solutions onto the cuttings throughout the working day for five days a week for two weeks; within a few days, cuttings receiving the highest concentrations of zinc showed symptoms identical to those affected in the previous year.

The cause of die-back seemed to have been established; it was the zinc content in the high pressure water from the pre-treatment of the radio communication tower. But the boron levels in the leaves nagged at us. Had we overlooked something? The explanation in the end was mildly annoying—the sample used in the original analysis, though large enough to detect zinc, was far too small to detect boron.

The moral of our story is that, if your nursery is located near a radio communication tower or, indeed, any structure where high-pressure water is used to remove old paint, we suggest you consider relocating. More seriously and with hind-sight, this die-back problem presented a practical dilemma about where to go to get help. We would have like to have pressed an emergency button which would have immediately brought a team of experts to the nursery to collect samples for analyses for pathogens, for leaf analysis, for potting-mix analysis, for water analysis and for the analysis of whatever else might be considered desirable and hopefully, within a week, get them all together to pool their combined finds and wisdom, and suggest what to do.

LOW COST PROPAGATION OF EUCALYPTS

D. K. MCINTYRE and W. WOODRUFF

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Canberra, Australian Capital Territory 2601

Over the past few years there has been an increased awareness of the need to plant trees in Australia. This has been of particular importance on agricultural land, which is being degraded at an alarming rate. Various bodies such as "Greening of Australia" and the "National Tree Program" have launched major programs of rural reafforestation.

A large number of ingenious methods have been tried, both in the raising and establishment of trees with varying degrees of success to support these programs. There appear to be three major problems to be overcome for these programs to succeed.

Firstly, plants must have a very low cost so that farmers, reserve managers, and other interested groups with limited budgets can afford to plant and establish significant numbers of trees.

Secondly, these plants must be easily handled and transported in the field, be inexpensive to plant but still with sufficient growth potential to establish quickly when planted out.

Thirdly, it is essential to ensure high establishment rates with minimum cost.

In most of Australia the climate is harsh, with high summer evaporation rates, (and often the soils are poor). Under these conditions transplant shock and desiccation often cause high plant losses during establishment.

In the 1960's APM Forests in New South Wales and Victoria developed a method of growing eucalypts in small compressed peat pots (Jiffy Pots) (1). This technique met with considerable success in the establishment of forestry plantations.

The ACT Parks and Conservation Service decided to use a similar method in field trials with eucalypts for use in the production of firewood lots, and peri urban landscaping in the ACT.

Low survival rates often occur after planting out into the field, and this is costly. Transplant shock due to root damage and water stress is probably the most common problem. There is a loss of growth potential, die-back of roots and young shoots, and quite frequently, death.

If an improved or more constant supply of water to the roots could be achieved in this early stage of establishment, much of this plant damage and death could probably be reduced.

Super absorbents such as acrylamide polymers, can be used to trap gravitational water and hold it in the vicinity of the roots. A compound such as Austrasorb® is capable of holding many hundreds of times its own weight (approximately 500) of water at a pressure of one to two atmospheres, making it readily available for plant roots. It was decided to use Austrasorb in the establishment of the trees grown in the smaller-sized Jiffy Pots to try and decrease the percentage loss due to early desiccation.

MATERIALS AND METHODS

Because of Canberra's harsh climate it was decided to grow the plants in a glasshouse rather than in an outside nursery, with a short hardening-off period outside before planting. In the initial trial 30,000 eucalypts of some 70 different species were raised in 57mm × 57mm × 50mm Jiffy Pots; 30 pots were fitted into a standard 285mm × 340mm plastic seedling tray.

The soil mix was 75% washed river sand 25% peat moss. The seedlings were raised in punnets and pricked out one per pot at the two leaf stage. They were watered with an automatic overhead watering system in a glasshouse, and fertilised twice a week with Aquasol at full strength. The seedlings were grown in the glasshouse for about 4 months during winer then taken out for hardening off in early spring. They were planted out in spring into sites prepared by deep ripping and disc ploughing. The seedlings were between 250mm and 380mm in height at planting.

Establishment rates were high and growth was good during the first summer and autumn, and as a result a second small trial was set up to see whether the cost of production could be reduced and more flexibility could be achieved by controlling growth, and reducing the pot size without affecting the good establishment rates.

Plastic seedling trays 285mm × 340mm were filled with 72 Jiffy Pots (in cards of 12) 36m × 36m × 50m. The pots were filled with a washed river sand which had no added soil or nutrients. A fine layer of ground dry peat moss was sprinkled over the top of the sand to prevent seed falling down into the voids in the sand as well as providing moisture for germinating seed.

Four species were used, *Eucalyptus globulus* subsp. *bicostata, E. cinerea, E. mannifera* subsp. *maculosa* and *E. melliodora*. Four trays of each species (308 plants) were used. Seeds were sprinkled onto the surface, making sure that each pot received 3 or 4 seeds. When the seeds germinated they were thinned to one per pot by cutting the excess off at the ground level with a small pair of scissors. This process is the most time consuming one in the operation, but with practice can be done very quickly. The seedlings were fertilised twice weekly with alternate applications of full strength Aquasol and Phostragen. When the seedlings were about 150mm high they were moved out of the glasshouse and hardened off under 50% shade.

A site was prepared for planting by ripping. Single rip lines were made about 450mm deep and about 2 metres apart. The seedlings were planted into the rip lines and no water was added at the time of planting. There had been no rain on the site for two weeks. Four rip lines were used, the plants in one line were given no treatment and all plants in the other three lines were given about 1gm of Austrasorb added as a gel made up at a rate of 1gm Austrasorb to 300cc of water. The gel was added into the planting hole, and the Jiffy Pot was placed in on top of it. About half the plants were planted out in this initial trial in late February, when conditions were quite hot and dry.

A second planting was done about three weeks later using the remainder of the plants. Three quarters of the plants were treated with Austrasorb as before and the remainder were left untreated. This time, however, all plants were watered in using about 10 litres of water per plant immediately after planting.

One tray of plants was kept for about five months. It was watered and no fertiliser was added, to observe what affect this would have on future planting stock.

RESULTS

The seedlings raised by the above method were well suited for large scale planting. They had well-developed root systems and were easily separated from each other. There were no problems with growth and the sandy medium gave good aeration for healthy roots (Figure 1).

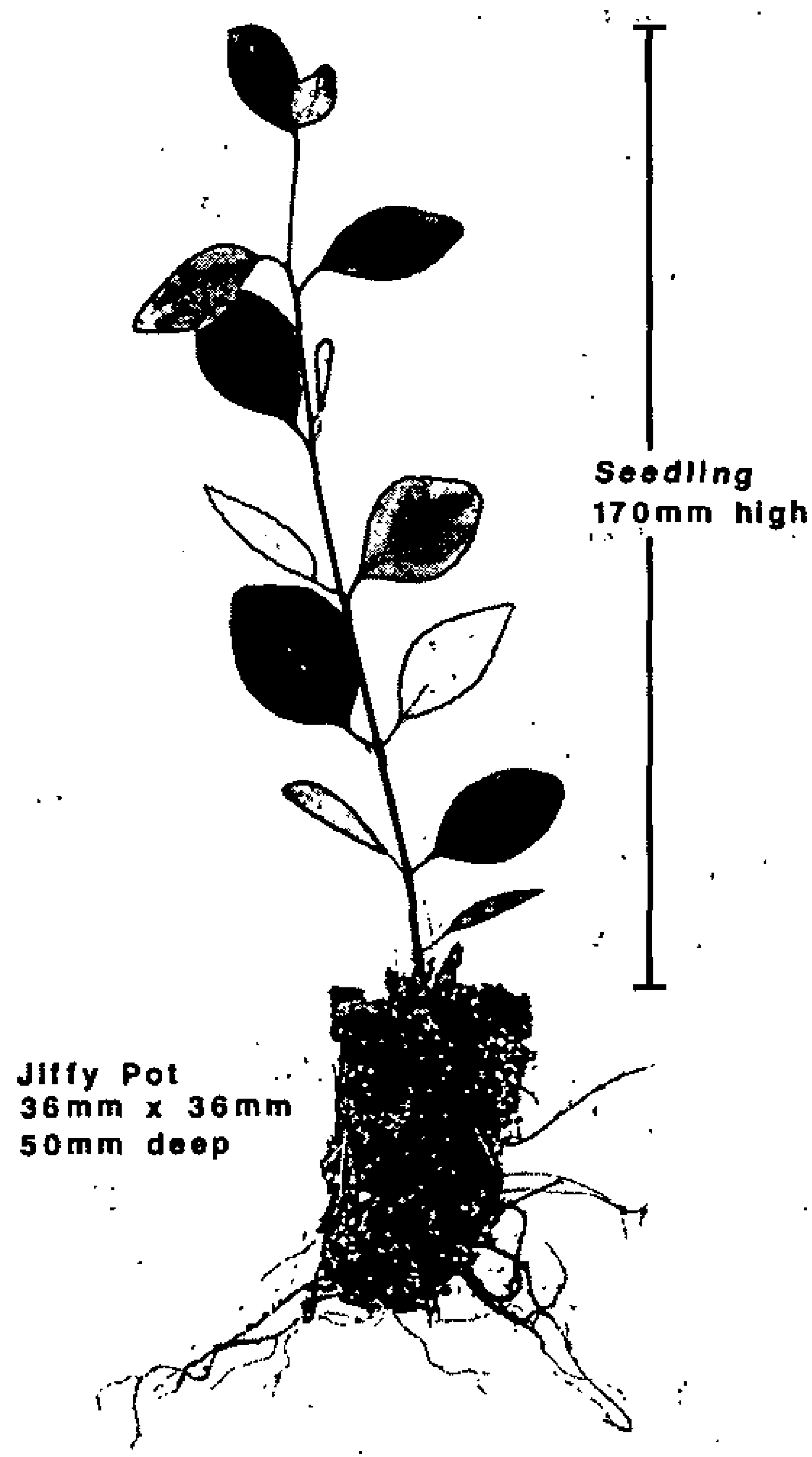

Figure 1. Eucalypt seedling grown in sand in a Jiffy Pot.

This method allowed large scale production—up to 30,000 in an 18m × 6m glasshouse using 57mm × 57mm Jiffy Pots, and 72,000 in the same area in the smaller 36mm x 36mm pots every four months. The cost of production of the seedlings in the larger Jiffy Pots was about 45¢ per plant, and about 20¢ per plant in the smaller containers.

The single tray of seedlings, which were kept in the tray for several months, ceased to grow when the fertiliser ran out, and turned a reddish colour. They remained in this state of suspended growth provided they were watered regularly.

After about 5 months they were fertilised with Aquasol several times, and quickly greened-up, commenced to grow, and were successfuly planted without any apparent deleterious effects. These plants are now growing vigorously.

The large scale planting of the eucalypts in the 57mm × 57mm Jiffy Pots was very successful with above 90% establishment rate in the field. This was a spring planting and there were very few losses in the first summer.

In the first trial using the small Jiffy Pots, after 3 months there was about a 70% survival with the Austrasorb-treated plants, and only about 15% survival of the untreated ones. These plants received no water at planting and it did not rain for more than three weeks. The larger-leaved faster-growing *E. globulus* subsp. *bicostata* seedlings suffered more damage and death than the other species used.

In the second trial using the small Jiffy Pots, the survival rate after establishment and two months growth was 95% in the Austrasorb-treated plants and about 50% in the untreated plants.

DISCUSSION

This method of raising eucalypt seedlings in Jiffy Pots in a glasshouse is very efficient and cost effective. The smaller Jiffy Pots (36mm × 36mm) are also quite suitable, provided the seedlings are planted when they are below 250mm in height. Larger plants may be harder to establish. The cost of production of this sized plant is very low, relative to other techniques, and is suited to low budget or large scale plantings.

Both sizes of Jiffy Pots produce plants which establish easily in the field, with very high success rates. Planting into rip lines is the recommended method. The use of the super-absorbent Austrasorb greatly increased the survival and early growth potential of the young plants.

This propagation method and establishment package is recommended for eucalypts, particularly for farm plantings. As with all other planting techniques, follow-up weed control is essential to ensure that the seedlings become trees.

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NON-ASTRINGENT PERSIMMON PROPAGATION IN SOUTHEAST QUEENSLAND

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INTRODUCTION

The persimmon (*Diospyros kaki*) is native to China and Japan. Most of the development of the crop has been done in Japan where the persimmon has been considered as its national fruit. In 1987, domestic production of the persimmon in Japan was 309,000 tonnes; the fruit is consumed both as a fresh fruit and a processed product. Persimmon industries are now being developed in Australia, New Zealand, California, Israel, and Italy.

Evaluation of the persimmon in southeast Queensland has primarily been aimed at making better use of frost-prone, marginal, horticultural land unsuited to most other tree crops. There is the potential for exporting "out-of-season fruit" to Japan, other Asian countries, and Europe as the fruit is much sought after in these countries.

At this stage there are approximately 15,000 trees planted in southeast Queensland and market prices in Brisbane for 1987 have been firm. The use of top quality, uniform planting material is critical in the establishment of any orchard. In southeast Queensland there have been variations in the success of persimmon propagation techniques.

PROPAGATION TECHNIQUES

Rootstock Selection. There are three rootstock species commonly used for persimmons in the world.

1. *Diospyros kaki*—Japanese/oriental persimmon;
2. *Diospyros lotus*—date plum (native to China);
3. *Diospyros virginiana*—American persimmon (native to midwest and southeast United States).

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Of the three rootstock species used, *D. kaki* is the most preferred in southeast Queensland due to its compatability with all cultivars. In southeast Queensland, there are more than twelve local selections of *D. kaki* which show adaptation to their local area. There have been sporadic incompatability problems with some nonastringent persimmon cultivars, such as 'Fuyu', grafted onto date plum (*D. lotus*). This has not been evident in all cases and it seems to be related to different strains of both rootstocks and cultivars.

There is one method of determining the identification of a particular rootstock species (1). A sample of bark or portion of an old root found well below the soil surface is placed in a test tube with 15 times its weight of distilled water. The test tube is left to stand for one or two hours. At this stage a slight colour change will occur denoting a difference among species, namely: *Diospyros kaki*—amber; *Diospyros lotus*—yellow; *Diospyros virginiana*—light yellow to colourless.

By decanting off the liquid and adding a few drops of a weak sodium hydroxide solution, the colour change becomes more pronounced, i.e.: *Diospyros kaki*—wine red; *Diospyros lotus*—light amber; *Diospyros virginiana*—light yellow to colourless (l).

The identification of a rootstock species can be accurately determined using this method.

Seed Collection and Germination. Seed should be collected from mature but not decomposed fruit, as seed from decomposed fruit has a low to nil germination rate. Generally persimmon seed should be stratified at 10°C for 60 to 90 days (2) although upwards of 80% success has occurred if seeds are sown immediately after extraction from the fruit. Seedling variation in both vigour and uniformity can be large especially with local selections. The source of seed becomes a very important consideration for uniform rootstocks. Seed is generally collected from a known local selection or imported from Japan.

Budding and Grafting. Persimmon scion cultivars can be propagated by either budding or grafting. Grafting is more successful than budding but should be done before the commencement of sap movement which occurs in late August/early September (late winter to early spring). Whip or cleft grafting is the most successful with a greater than 95% success rate. High humidity (70 to 80%) favours a good take and this can be achieved by placing plastic bags over the entire scion and graft union after taping. Callus forms very rapidly under warm conditions (22 to 25°C) and the bag also protects the soft new shoots from the drying effect of the wind. After 14 to 20 days the plastic bag is untied but not removed until 36 to 48 days. Once removed the plants are grown on and hardened off for planting.

Budding can be done in the early autumn period (late

February/early March). Chip budding has been more successful than T-budding (70% and 50%, respectively). Even with a lower success rate from budding in early autumn, there is the added advantage of producing enough growth for planting out in winter.

Cutting propagation. There has been no work carried out in southeast Queensland on the use of cuttings or tissue culture in the propagation of persimmons. A major benefit which could come from these methods would be in the production of uniform rootstock material.

The potential of these methods in reducing variability among plants is still to be realised in southeast Queensland.

CONCLUSIONS

The persimmon industry in Queensland is still at a very early stage in its development and aspects of orchard production are still being evaluated.

High density orchard plantings, specifically for earlier and higher yields, require a less vigorous tree capable of performing well in all situations. This could be achieved through the use of low vigour or dwarfing rootstocks, clonally propagated to ensure uniformity.

The selection of rootstocks may rely on a local selection with good adaptation to local conditions (drought tolerance, salt, waterlogging, climate).

As the persimmon industry in southeast Queensland starts to develop further, the direction for future propagation needs will be more adequately assessed.

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PROPAGATION OVERSEAS—AN OVERVIEW

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This paper contains impressions observed in California and in the United Kingdom gained as a result of a Professional Experience Program undertaken in 1986. The primary aim of the program was a teaching exchange with a lecturer from the Merrist Wood Agricultural College in Surrey, England. The Nursery Department of the Merrist Wood College concentrates primarily on the Hardy Ornamental Nursery Stock Industry (H.O.N.S.) and the scope of this paper reflects that specialisation.

THE PROPAGATION ENVIRONMENT

The range of propagation environments I wish to include are: mist propagation; fog propagation; greenhouse tent propagation; sun tunnel propagation.

Mist Propagation Although now regarded as an outdated propagation environment by many propagators, mist propagation was observed in a variety of situations which demonstrate the unique flexibility of the system. In the predictably dry summer climate of southern California, outdoor mist propagation is widely used in nurseries. A variety of control devices are in use but time clocks appeared to be the most common. Outdoor mist propagation is used for around six months of the year from April to September with good results. A wide range of hardy shrubs, ground covers and perennials are propagated during that summer period. Because of the increased risk of desiccation of cuttings propagated outdoors, softwood cuttings are avoided and firmer semi-ripe cuttings selected. It is also common practice in California for mist propagation to be used in shadehouse structures. Similar seasonal limitations apply and softwood cuttings are avoided.

The erratic summer climate of the United Kingdom precludes any use of outdoor mist and all mist propagation is located in fully enclosed greenhouse structures. The high capital cost of greenhouses makes it imperative that the structures are utilised all year round. Greenhouse space heating and bench or bed heating are essential in winter use of mist propagation. Trials carried out at the Efford Experimental Horticulture Station in England suggest that a basal temperature of 18°C is desirable.

The hardy ornamental nursery stock industry is able to utilise mist propagation successfully all year round for a wide range of deciduous and evergreen shrubs with softwood cuttings used in spring and early summer, semi-ripe cuttings through summer and autumn and ripe evergreen cuttings throughout the winter period.

Accurate control of the misting sequence is vital in winter to prevent overwetting of the propagation medium and depression of the temperature of the medium—two problems commonly experienced in the use of mist propagation during the winter in Britain.

Fog Propagation. The relatively coarse droplets produced by impact type mist sprinklers means that the droplets cannot remain suspended in the air for any length of time. They precipitate out onto the cuttings very quickly and this leads to overwetting. As a means of humidity control, mist propagation is rather crude and it is gradually being replaced in many nurseries by fog propagation.

Fogging equipment produces a much smaller droplet (10 to 30 microns) which remains suspended in the air for a considerable time. This provides a propagation atmosphere with a high humidity and reduced risk of overwetting the propagation medium or leaching the foliage of the cuttings.

Three types of fogging equipment are commercially available:

(i) *Ventilated Fog:* A large propeller fan mixes large amounts of air with a water supply which is broken up into fine droplets by a spinning disc and blows the water stream through the greenhouse. No compressor is needed for this system, which makes it the cheapest alternative. The air turbulence also creates an evaporative cooling effect. The principal disadvantage is that a humidity gradient is created; overwatering can occur close to the outlet but the furthest areas of the greenhouse will be substantially less humid.

(ii) *Pressurised Water Fog:* A compressor is used to force water at high pressure (up to 600 p.s.i.) through stainless steel micro-nozzles. This produces the finest droplet size (as small as 10 microns) which will remain suspended in the air for a long period. This is a much more expensive option but provides the best control of the propagation atmosphere.

(iii) *Pressurised Air/Water Fog:* Compressed air and low pressure water are mixed in special sonic nozzles which create a shock wave which results in small fog particles being produced. This system is a compromise option; it is not as expensive as pressurised fog but is more uniform in its effect than ventilated fog.

Work carried out at Efford Experimental Horticulture Station suggests that shading of the greenhouse in summer is essential to reduce greenhouse temperatures since ventilation is not possible. Lining of the inside of the greenhouse with polythene film has been found to reduce the rate of fog dispersion.

Fogging equipment is probably the most sophisticated propagation equipment available but its effectiveness depends largely on the control of the equipment. Simple time clock control is one option which is used but the plant propagator must be able to observe environmental changes and make alterations to time clock settings as necessary.

A number of humidistats are available which in theory can be set to provide a constant level of humidity. In practice, these devices must also be monitored regularly and adjustments made.

Greenhouse Tent Propagation. Although this would be considered a low technology option in cutting propagation, the use of greenhouse tents is widespread in English nurseries, particularly in winter. The low winter light levels mean that benches which are overwetted remain wet for prolonged periods which can lead to depressed media temperatures and substantial losses through waterlogging and pathogen attack.

Clear plastic sheeting is commonly used and supported above the plants by a wood or pipe framework. The edges of the polythene are usually sealed or tucked in to reduce moisture loss.

Cuttings may be direct stuck in a layer of rooting medium on the bench or they may be planted in trays. Watering is done very sparingly by hand and every care taken to avoid overwatering. It is common practice to periodically remove the plastic cover to ventilate the cuttings and allow some drying to occur to avoid too much free water underneath the plastic. Clear plastic sheeting with a regular pattern of perforations is available and widely used in winter. It allows some drying out to occur and helps to prevent overwet conditions.

Basal heating is an advantage in the initiation of roots; 15 to 18°C is commonly used as a base temperature. Electric heating cables and warm water pipes were both observed as heating methods.

In a number of establishments the propagation tents were located at floor level in the greenhouse with basal heating incorporated in the greenhouse floor.

Plastic tents are used in many nurseries throughout the year and the late spring-early summer period is a peak season for cutting propagation. Some shading may be necessary with softwood cuttings at that time of year. This can be achieved with white paint or shade-cloth. After rooting, a progressive reduction in shading is desirable to harden off the cuttings prior to removal.

Sun Tunnel Propagation. The sun tunnel is a modification of the traditional cold frame which has been developed in England as a low cost outdoor propagation environment for easy to propagate shrubs and perennials.

The basic structure is a low tunnel frame made from high tensile wire or galvanised pipe covered with a polythene sheet. The dimensions can be adjusted to suit individual requirements but sun tunnels observed in England were commonly 0.75 to 1.2m wide and

0.5m high in the centre of the tunnel.

The sun tunnel can be used as a means of striking cuttings of low shrubs and ground covers directly in the natural soil beneath the tunnel. After rooting, the cuttings are hardened off *in-situ* and the tunnel finally removed. The young plants can then be grown on in the ground until the end of the growing season.

Alternatively, cuttings can be planted in trays and removed for potting after hardening off. If cuttings are direct-planted in the ground, a 3cm layer of propagation medium is spread on top of the natural soil for initial root development. Soil fumigation with Basamid is commonly done to eliminate pathogens from the soil prior to commencement.

For summer propagation of softwood cuttings the incorporation of a mist or irrigation line is essential so that regular watering can be carried out. The use of shading or white polythene film is also recommended in summer.

Winter use of sun tunnel propagation was also observed. A range of easy to propagate evergreen shrubs can be raised from ripe evergreen cuttings planted in autumn. For winter propagation it is recommended that cuttings be planted in the soil rather than in trays. White plastic sheeting is used but the incorporation of an irrigation line is not necessary. Cuttings are thoroughly watered-in after insertion, a routine fungicide spray applied, and the tunnel sealed up until spring.

Where the sun tunnel is used to propagate fast-growing, easy-to-root shrubs and perennials a high degree of success can be achieved. Plants which are considered difficult to propagate should be propagated in a more controllable propagation environment such as greenhouse mist or fog.

DIRECT STICKING OF CUTTINGS

In the propagation of cuttings in England, the normal pattern of production occurs in three stages:

(i) Root development in propagation container;

(ii) Growing-on rooted cuttings in liner pots;

(iii) Growing-on in final sales container.

In recent years the practice of propagation direct in a 7cm or 9cm liner pot has developed. A peat-based rooting medium with controlled release fertiliser incorporated is used. The "EMPOT" tray system is widely used as a unitised system for liner production. Cuttings are direct stuck in the liner pots and the cuttings rooted under mist, fog, or tent.

Direct-stuck cuttings enable the faster growing lines to be produced to a saleable size in a much shorter time than by conventional methods, a 50% reduction in production time being achieved with many plant types.

The trade-off for faster production using direct sticking is an increased propagation space requirement. To maximise production output in the propagation stage it is not advisable to use this technique with species that have a low success rate.

MICROPROPAGATION OF LAVANDULA SPECIES

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Abstract. A micropropagation method for *Lavandula angustifolia* 'Rosea' is described. Shoot tips and nodes were sterilized and placed on a basic Murashige and Skoog medium with Linsmaier and Skoog vitamins, supplemented with 0.3 mg/l benzylaminopurine (BAP). Under culture conditions of light intensity, 2000 lux; photoperiod, 16 hours; and temperature, 25°C, the shoots elongated and axillary growth formed. After 4 weeks the resulting axillary shoots and nodal sections could be used for further multiplication or as cuttings. The cuttings were rooted on a half strength Murashige and Skoog medium supplemented with 1 mg/l indolebutyric acid (IBA). The rooted plantlets were then gradually acclimatized to the greenhouse environment with a 98% success rate.

REVIEW OF LITERATURE

A method has been devised to propagate the pink flowering lavender, *Lavandula angustifolia* 'Rosea', to provide adequate stock plants for a specialist herb nursery. The method was also successful with the common lavender, *L. angustifolia*, grown at the Department of Scientific and Industrial Research (D.S.I.R.) Lincoln, New Zealand, for assessment in viability trials for lavender oil production.

The technique involves the multiplication of axillary buds, which extends the more restricted work of Quazi in 1980 (1), and avoids the use of callus for plantlet formation which is not always suitable for clonal propagation.

The new techniques in plant molecular biology use programmed bacteria to pass messages into plants. At the moment these messages are passed mostly by bacterial genes which confer resistance to pesticides or disease in the host plant. It is hoped that in the near future plant genes for quality, or ripening, or oil production, or increased fragrancy will be introduced.

To increase the number of such transformed plants a method of propagation is required which ensures the production of true clonal propagules. The propagation of plants from axillary buds, rather than from adventitious buds or callus, is one such method. It lessens the chance of genotypic changes—or somaclonal variation—thought to be stimulated on proliferating tissue by the culture conditions. Stock plants built up in this way will be more true-to-type and this will be retained in the field plants which will be increased by conventional cutting methods.

The technique described below on the micropropagation of *L. angustifolia* 'Rosea' shows that this is feasible.

MATERIALS AND METHODS

The *L. angustifolia* 'Rosea' plants were held in an acclimatization area, at a temperature of 25°C under low light conditions of 1000 lux and sprayed with a Benlate-thiram fungicide mixture. The new shoot growth consisting of nodal sections with a shoot tip 1 to 2 cm in length, were used as explant material. Disinfestation was achieved with a wash in 0.6% sodium hypochlorite for 20 mins, followed by three rinses in sterile distilled water, and a final dip in 0.2% sodium hypochlorite before plating.

The basic medium trialed for shoot multiplication, contained full and half-strength Murashige and Skoog minerals (2), with Linsmaier and Skoog vitamins, 30g/l of sucrose, 7g/l of Davis agar, with the pH adjusted to 5.7. The strengths of hormones tested were 0 to 1 mg/l BAP, and 0 to 2 mg/l kinetin combined with 0 to 2 mg/l napthaleneacetic acid (NAA). The culture conditions were temperature, 25°C; photoperiod, 16 hours, and light intensity, 2000 lux.

The medium used for root formation was half strength Murashige and Skoog minerals with Linsmaier and Skoog vitamins, 30g/l sucrose, 7g/l Davis agar, with the pH adjusted to 5.7. The hormones tested were indoleacetic acid (IAA) at 1 to 10 mg/l, NAA at 1 to 10 mg/l and IBA at 1 to 10 mg/l.

RESULTS

The explants rapidly grew new axillary shoots. These shoots were cut and subcultured onto a number of media and, although there was initially some vitrification and etiolation, this was overcome by the use of a higher light intensity.

The media containing BAP levels of 0.5 to 1.0 mg/l, and kinetin at 0.5 to 2.0 mg/l, or in combination with the auxin, NAA at 0 to 2.0 mg/l, all showed poor shoot growth, and produced callus. Successful axillary shoot production with a 4 to 5 fold multiplication rate was obtained using full strength Murashige and Skoog minerals with 0.3 mg/l BAP, or 0.3 mg/l kinetin. (Table l) The reduction of hormone levels to 0.1 mg/l BAP or 0.1 mg/l kinetin one month prior to rooting enhanced the rooting percentages slightly.

Cuttings from the axillary shoots rooted most successfully on half-strength Murashige and Skoog minerals with 1.0 mg/l IBA. (Table l) The roots were established after 4 weeks and the plantlets transferred to soil.

The rooted shoots were rinsed in tepid water containing the fungicide "Euparen" (dichlofluanid, diluted to 1%). They were planted in pumice-sand without fertilizer, and hardened-off in a greenhouse under mist-spray, with further use of a weak fungicide, e.g. "Ridomil". There was a 98% survival rate. After two months they were potted into 7cm propagation tubes and placed in the shade house.

Table 1. Media for the micropropagation of *Lavandula angustifolia* 'Rosea'.

Murashige and Skoog mineral medium at full strength, supplemented with:	
myoinositol	100 mg/l
thiamine HCL	0.4 mg/l
sucrose	30 g/l
Davis agar	7 g/l
pH	5.7
Shoot multiplication:	
BAP	0.3 mg/l
Pre-rooting:	
BAP	0.1 mg/l
Root elongation:	
Murashige and Skoog mineral medium half-strength, supplemented as above, and IBA 1.0 mg/l	

DISCUSSION

The micropropagation technique for *L. angustifolia* 'Rosea' was devised for an initial order of 1000 plants. The successful shoot multiplication rate, root development, and transfer to soil, show this to be a feasible commercial production programme.

The *L. angustifolia* from D.S.I.R., Lincoln, has followed a similar pattern, and plantlets have been transferred to soil. Since the propagation of the lavender plants is from the production of axillary shoots, it would be a practical method for use in a molecular biology programme for the improvement of lavender crop production.

Acknowledgments The author wishes to thank Rhiannon Edwards and John Braithwaite of Lifetech Laboratories nursery staff for advice on transfer to soil. Also to Dr. J. D. Ferguson, for assistance with plants, and constructive discussion on the paper.

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WHAT SHOULD WE COVER THE GREENHOUSE WITH?

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Increasing costs in production and demand on our product, the ornamental shrub, has made it necessary to achieve a fast turn around in growing-on-line (G.O.L.) production to maintain any profitability in the industry.

This has meant better structures and, most of all, better coverings. The more efficient the covering the better the product, enabling us to force it along in cold weather, protect it from cold winds, excess rain, hot sun, heavy frost and hail.

For this paper I would like to describe two weatherproof films and one woven fabric that we use in our nursery.

PVC Hyperlyte

Polyethylene woven fabrics.

Knitted polyethylene shade cloth

PVC "Hyperlyte" greenhouse film. "Hyperlyte" greenhouse films are formulated from P.V.C. and have been developed in New Zealand to provide a greenhouse covering of the highest possible strength. They are available in two standard light transmission formulations: the clear formulation, providing 89% transmission of the visible light spectrum; and the white shaded formulation which gives a shade level of 50%. This shaded formulation is particularly suited to propagation house application.

P.V.C. films have very low transmission levels of the long wave radiation (thermal). This feature means that they contain greenhouse heat better than other single skin, flexible cladding materials. They are UV treated.

P.V.C. films are highly resistant to tearing, even in the most severe storm conditions. Small punctures can be readily repaired with solvent-adhered patches.

While standard roll width is only 1350mm, "Hyperlyte" can be supplied as fabricated covers, high frequency welded to any dimension, thus overcoming the problems associated with joints.

Under normal conditions a usable life expectancy of these films would be approximately 5 years. However, considerably longer usage had been experienced under some conditions, but these must be regarded as exceptions.

"Hyperlyte" films are suitable for structures of the tunnel type or for the cladding of houses of the more traditional gable type.

Woven polyethylene. Trade names: "Fabricon," "Solarweave."

Designed especially for the horticultural industry, a UV treated cross-woven fabric that resists ripping and tearing and other operational hazards. Available in three formulations:

Fabricon: One-sided UV polyethylene coating

Solarweave: Natural two-sided UV polyethylene coating

Solarweave: White two-sided UV polyethylene coating

Natural fabric has an 83% light transmission.

In our experience the one-sided materials give a dryer atmosphere or lower humidity. These are ideal for young tubed crops such as *Grevillea, Protea,* or *Leucodendron.*

After the underside of the cover has aged, the woven material does not allow a great amount of condensation to form, thus less dripping occurs.

These materials can be fabricated either by sewing or hot air welding.

Knitted high density, UV-treated polyethylene shadecloth

This material, again developed for the horticultural industry, has strength, longlife, and greater width as its main features.

Knitted cloth has the advantage of being a very stable fabric using carefully monitored levels of UV treatment. It comes in varying shade percentages and colours—clear 10%, white 55%, and black, green and brown with varying percentages.

Another factor we found important was the material's ability to have an inbuilt "memory"—springing back into shape when depressed or bulged.

It is non-running, resistant to ripping, and has an optimum life of 10 to 15 years with the exception of white, with a 20% expected reduction.

DUNCAN AND DAVIES NURSERIES LTD, NEW PLYMOUTH

The range of greenhouse covering materials in New Zealand has increased dramatically over the last 10 years from glass and P.V.C. to fibreglass, twinwall acrylic, polythene, and more in a variety of brands and colours. This poses the perennial problem to the propagator on "what should we cover it with"! The four main factors in helping me to decide are:

The material best suited to one's requirements

Durability and longevity

Cost competitiveness

Service from manufacturer or supplier

I will give an outline of what we use on our nursery, and why.

The covering material for our propagating and growing-on tunnel houses is polythene. After trialling with various types of P.V.C. and polythene covers we decided to use "Agphane 101" brand. This plastic is polyethylene copolymer, available in 125, 150 and 200 micron (mμ) thickness, in clear and 40% white tint, with a three year warranty on the 200 mμ provided it has the hoops covered with protective felt strips.

These houses have inflated double-skinned 200 mμ covers, the inner being clear and the outer white-tinted. This gives even light spread, but reduces the glare. The double skinning keeps the night temperature up to 5°C. warmer on frosty nights, and 2°C. cooler in the heat of the summer.

Eight years ago we used black shade cloth covers for shading these houses during the summer. While providing adequate shade this also increased the midday temperatures up to 6°C. We then changed to pink glasshouse shading paint of which we applied up to three coats. The disadvantages with this system were that it was time consuming to apply and as the covers become rougher with age the paint becomes increasingly difficult to remove in the winter, especially on P.V.C. Two years ago we began changing to our present system of the outer white-tinted cover, with one coat of pink shading in summer, which to date is working well.

Side vent tunnel houses (cold growing-on houses) are covered with 125 or 200 mμ clear covers—we are gradually changing to all 200 mμ, in the autumn to spring/early summer. Black shade covers are slid over the top if required during sunny periods. We have found the clear covers give better plant growth than tinted ones in this area. These houses are covered with polythene in the winter to encourage plant growth by keeping them warmer with the clear cover and also dryer with our high rainfall (approximately 65 in. per annum). The "side vent" is also important to keep humidity levels down to reduce fungus disease problems. They are also labour-saving because instead of shifting plants we change covers; this is, poly in winter, shade in spring, or when hardening off, then no cover to fully harden off.

Technical information available comparing "Agphane" plastic to other cladding materials is:

(i) The heat retention in double-skinned polythene (not specifically Agphane) heated houses is in the top of the range with only double-skinned P.V.C. being superior.

(ii) Ultraviolet and condensation tests by P. R. Thompson in 1983 (1) found "Agphane 101" was still in good condition and flexible after 3213 hours of continuous testing. This put "Agphane" at the top of the list with these tests against comparable plastics.

(iii) When tested for photosynthetically active radiation and spectral transmissivity 'Agphane 101" was in the same ranking as horticultural glass, whereas most other plastic covering materials were 10% to 30% lower.

Under test conditions "Agphane" was proven to be the superior plastic. It was also the first to have a three year warranty for the 200mμ grade. These are some of the reasons why we use it, but it also is standing up well to our regular high winds. They are staying flexible with regular removal and storage, not weakening or becoming brittle at folds when stored. It is cheaper for us than other plastics, $100 to $150 per cover depending on size, and 50% cheaper than P.V.C. We also receive prompt service, which was not always the case with other manufacturers.

The other type of propagation house covering material used is twinwall sheeting on a five bay multispan house. The brand is "Qualex" which is extruded from a grade of "Lexan" transparent polycarbonate. A similar material is "Acrylflute", an impact modified acrylic resin, both of which are of the same structure, that is double-skinned sheets reinforced by structural ribs.

In comparison to the "Agphane", "Qualex" transmits 90% of the light of horticultural glass, with better "light scatter"; that is, the light is not as intense but diffused and more evenly spread through the house.

Heat retention, although not as high, is still in the top of the range making this sheeting more efficient than glass, fibreglass, single-skinned polythene, or P.V.C.

It has high ultraviolet stabilizers and is very flexible. It expands and contracts with temperature fluctuations giving a wrinkled effect along walls but it remains flexible and air tight at joints.

In tests for photosynthetically active radiation and spectral transmissivity "Acrylflute" was 10% to 20% lower than horticultural glass depending on density.

"Qualex" is much more costly (up to 4 times dearer) than polythene but expected life is 15 years or more compared to about 4 years for 200 mμ polythene. The extra initial cost balances out over its life span.

Our reason for building this expensive structure (the framing was about 3 times the cost of a tunnel house) was it is a dual purpose export packhouse for 4 months of the year and a propagating house for the balance, rather than having two separate structures. This house is better suited to larger lines of cuttings that require lower humidity than the tunnel houses. It is good with roof-suspended mist lines allowing machinery access for putting in media for plunging grafts into or for establishing newly-potted growing-on lines during quiet propagating periods.

Shade cloth materials used on the nursery have been a 50% black polyester cloth and to a lesser extent Sarlon 50%. These cloths come in 1.8 metre widths which are sewn together into the appropriate size for our houses. The covers are fastened to houses by ropes through pockets on the ends and nylon cord through clips on the sides.

Both of these cloths are woven and their main drawback is that if they are cut or wear, the cloth continues to fray, unless repaired quickly. They are also available in one width and different percentages of shade.

These covers are used for:

Permanent shade houses

Temporary shade-on-side vent houses

Summer shading to optimize plant growth and hardening crops off from heated houses.

Their life expectancy with us is 10 years in a fixed shadehouse situation or 8 years where they are continually changed on tunnel houses.

We are now changing to "Duranet" shade covers as this knitted material doesn't fray, is available in a range of widths, different percentages of shade and colours and is very favourably priced compared to other cloths. This will solve some of our problems, especially with some natives such as *Corynocarpus* which require heavier shading—we will now be able to put on a denser cover, say 70%, rather than having crops scorching or putting on two covers, which is not easy.

Every nursery has to decide what is best for their requirements as there are many variable factors, such as sunlight levels, weather conditions, types of crops grown and existing nursery structures.

Acknowledgments I. Fankhauser wishes to thank Agplastics, Christchurch, for supplying technical data.

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NEW CROPS TO CONSIDER FOR NEW ZEALAND AND AUSTRALIA TO ENTER THE WORLD MARKET

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The world trade in floriculture products has expanded during the past 10 years. This trend is increasing at a rapid rate. Actual production from various countries, and their projected output for the next decade, have been adequately published in the Floriculture World Trade Magazine (2), a magazine that had its origin and start in the Netherlands in 1982. More and more people, especially in the technologically advanced nations such as Europe, USA, and Japan have more and more disposable income that they can spend on florist products. This increase has been noticed by the third world countries wanting to enter the world floriculture market.

There are other good reasons why these countries are seriously looking into flower production, especially the Caribbean basin countries. Growing flowers gives a better return per square meter or per hectare when compared to other agricultural products. Flower production is labor intensive, thereby providing more employment for the local work force. This is why third world countries currently are actively seeking to gain information, technical expertise, and marketing specialists to fulfill their goals of exporting flowers.

Colombia, for example, has taken the lead in developing a domestic flower industry into a world market. They have developed streamlined flower production and the marketing channels that go with it. In 1970, Colombia's export in flowers only ranked 11th in their national export commodity measured in dollar value; today, in 1987, it ranks 3rd. To give an idea of how voluminous the export trade to the United States is, at Miami International Airport, where 60 percent of all flowers imported to the United States are landed, more than US $750,000 worth of flowers are handled every day of the year, the bulk of which originated in Colombia (1).

Now, what does this have to do with the topic of new crops to consider for New Zealand and Australia? The point is this: There should be no doubt in anybody's mind that there is a world market open for flowers, that the international industry is still in the expanding state, and that the market for the crops is still unlimited. Any country that is interested, provided it has the know-how, and can produce the quality that is acceptable, consistently and efficiently, has an equal opportunity in the world market for florist products.

I have seen in New Zealand the tremendous pressure to produce large quantities of better quality *Zantedeschia* tubers and flowers at cheaper prices. With the information on *Zantedeschia* that has been generated in the past five years, New Zealand is the leader in *Zantedeschia* production. However, the amount of flowering tubers that all the exporters of *Zantedeschia* produce in New Zealand cannot even supply the demand of Florida growers that want to force these tubers for the market if these growers go full steam in forcing *Zantedeschia* for the chain stores.

Thus, the market is there, now how about the crops? I personally feel that the crops that are exotic to you are difficult crops for New Zealand and Australia to produce, as well as to compete with others already in that market. As an example, attempting to grow alstromeria, nerines, carnations, mums, lilies, and the like in New Zealand or Australia for the world market would be a poor choice with limited potential, not because there is an adequate supply of these flowers, but mainly because the main flower-producing nations (Netherlands, Israel, Sweden, Africa, etc.) have cornered the market already. To be able to compete with those nations, producers in New Zealand and Australia would have to be more efficient, cost effective, and up-to-date, on the edge of the technical know-how, employ the latest mechanical equipment, and produce the best cultivars. To enter into this highly specialized business, when other countries can produce them so efficiently, is not an easy thing to do, not that it cannot be done. However, New Zealand and Australia would always be "trying to catch up" with the competition rather than being the leaders. Add to that the longer distance that these crops need to be shipped to the main markets, and this seems not a wise investment at all.

On the other hand, this should not be interpreted as a reason to eliminate the potential entry of New Zealand and Australia into the world market of flowers. What needs to be seriously looked into are methods to produce and export those flowers that New Zealand and Australia are familiar with, flowers that are relatively unknown and less exported in the world trade, but have proven to have long lasting qualities and, therefore can compete with other flowers with respect to postharvest life. This way, the margin of return can be somewhat adjusted to make it a profitable crop to grow and export, since other sources for these flowers are limited.

During the 1986 International Floriculture Marketing Seminar in Amsterdam November 2 through 4, Jeremy Pertswee, Chairman of Pathfast, LTD, Essex, England, stated that in order for prospective producers to produce marketable export flowers, they need to know the marketing chain and how much their product will cost the consumer. If the producer charges 100 units per box or bunches, by the time that product reaches the customers, the price would range from 624 to 800 units. Table 1 lists the increase of unit cost and where these increases go.

Table 1. Marketing index for flowers exported to the world trade market starting from the producer to the consumer.

	INDEX
Grower prices	100
Packing	120
Airport (departure)	125
Custom & forwarders	200
Duty	220
Clearance	225
Market commission	260
Distribution to florist (inland freight)	312
Florist mark-up	624–800

Crop yield: 50% average
Efficient growers: 60% to 70% (5% claims)
For tropical region producers: Later cost is higher
For European growers: Early cost is high; later cost is lower.

Let us see what are some of the flowering plants that have potential for New Zealand and Australia to export as cut flowers to the world market. Not much has been researched on some of these plants, but others have been studied for years by researchers in New Zealand as well as Australia. These researchers have accumulated a tremendous amount of data on prospective cut flower crops, and interested producers may obtain this information in order to help produce the crop and control its postharvest treatment. Below are listed some cut flowers that have potential, some of them are already being exported from New Zealand and Australia. The list is by no means complete but this should give prospective producers some ideas on what to look for in potential crops. These are crops that should be stressed, researched, and developed by the local scientists, crops that can be identified by the world market as being New Zealand and Australian specialties.

PROTEA

There is a variety of genera, more than sixty to be exact, that belong to the proteaceae family, of which around 1400 species have been identified. Familiar to many florists is one of the largest and most magnificent species of the protea family, *Protea cynaroides*, the king protea. Another species is *Protea magnifica*, the queen protea, and *Protea magnifica* 'Alba,' the varient of *Protea magnifica* which has pale greenish-white to rich, cream-colored bracts. *Protea neriifolia*, which is one of the more prolific bloomers of the protea family, and the slower growing specimen, *Protea grandiceps*, have beautiful bracts.

LEUCOSPERMUM

Leucospermums, or the pincushion flower as they are commonly called, are excellent cut flowers and have a vase life of up to a month without signs of desiccation or shriveling of the pincushion-like inflorescence. There are various shapes and colors in the *Leucospermum* species, ranging from pinkish yellow, orange, and salmon, to apricot colors.

LEUCODENDRON

Leucodendrons are dioecious plants, meaning that each plant is either male or female. One of the most colorful and widely used leucodendron is *Leucodendron salignum,* 'Safari Sunset,' developed in New Zealand. This was bred specifically for cut flower production purposes and is a female plant. It is very vigorous and fast growing, with an erect, bushy habit. Stem length, one of the outstanding features of 'Safari Sunset,' may exceed 60 cm. These flowers have excellent keeping quality, lasting up to sixty days in the vase without shriveling of flowers or bracts. 'Safari Sunset' is one of the most popular cultivars exported from New Zealand, and research needs to be initiated to discover if these cut flowers can be shipped in refrigeration by ship, rather than by air.

Other various species of the *Leucodendron* family that have potential for cut flowers as well as cut foliage are *Leucadendron xanthoconus,* which has small, lemon-yellow flowers borne on short stems and *Leucodendron argenteum,* the silver tree that grows 6 to 8 m high, has grey-green foliage overlaid with fine silvery hairs and has the potential to be used as cut foliage.

ANIGOZANTHOS

Commonly known as the kangaroo paw, *Anigozanthos* has generated interest in Europe and USA as potted flowers as well as cut specimens. There are at least 6 species of kangaroo paws, and most of them are very decorative and can be exported as cut flowers. Kangaroo paw is the most recent introduction to the florist trade, and presently the USDA and Florida are actively doing research on this crop to be used as a cut crop.

BORONIA

Boronia heterophylla, commonly known as simply boronia, has small, dark pink flowers borne on a straight stalk interlaced with attractive small, dark green leaves. They are widely used in New Zealand as landscape specimens and have a tremendous potential as an export crop. The fragrance of the flowers adds to the interest in this flower. Following harvest, the flowers remain on the stems and will not abscise or dry out and turn brown rapidly, as leptospermums do.

ERICA

Another interesting genus of flowering plants is *Erica*. The species come in many colors and shapes, the clustering, small flowers being borne on stiff stems. They are excellent cut flowers and are long lasting. They are used in New Zealand as landscape plants.

ORNITHOGALUM

A small bulbous crop, *Ornithogalum thyrsoides* flowers in early spring in New Zealand and has a tremendous export potential. The flowers are not bulky, and lend themselves very favorably for long distance air transport. There is only one color flower—white—but flowers lend themselves well to dyeing, so various color shades or colors can be obtained. *Ornithogalum* has long lasting flowers, and buds continue to open in the vase.

SANDERSONIA

Sandersonia aurantiaca has its origin in South Africa. The slender stems produce golden, urn-shaped flowers resembling Chinese lanterns. *Sandersonia* flowers have excellent keeping quality, and if placed in a preservative solution, flowers will continue to grow. Young flower buds develop and open normally.

ZANTEDESCHIA

Zantedeschia, or calla lily, has developed into a nice export flower for New Zealand, and Australia should follow suit. The new hybrids are showy, with long, stiff stems, large flowers, and excellent keeping quality. Colors are creamy white, light pink, yellow, golden yellow, maroon and dark red. Most cultivars have long-lasting flowers.

BANKSIA

These are slow-growing, large trees and are excellent specimens to grow as a commercial cut flower in New Zealand and Australia. The flowers are long lasting and can be used in dried arrangements. A lesser-known species is *Banksia coccinea,* a slow-growing plant with strong, leathery leaves and flowers that are borne on long stems; it is another cut flower that has potential. They are long lasting, and flowers become dry in flower arrangements without losing their color.

TELOPEA

This plant, the waratah, has one of the most colorful blooms. The plant grows into a large bush and the flowers are borne on long stems. This flowering plant should be promoted extensively in New

Zealand and Australia, since these flowers are magnificently beautiful with long-lasting qualities.

LATHYRUS

New Zealand has produced various cultivars of *Lathyrus odoratus* with long stems, and there is demand for *Lathryus* both in Europe as well as in the United States. Florists are familiar with them, and the new color variation and combinations that have been developed in New Zealand should be promoted and used more as an export crop.

In conclusion, New Zealand and Australia can offer the world market these flowers that are common in these two countries, but are exotic and exquisite flowers to the world market. New Zealand and Australia should concentrate on becoming specialists and leaders in these crops, rather than trying to develop crops that are already grown and marketed by other countries.

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PROPAGATION OF CHILEAN BELLFLOWER

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Chilean bellflower (*Lapageria rosea* Ruiz & Par.) a not so distant relative of Australasian flora, both geographically and botanically has been a fascination for me, often bordering on an obsession. This, in conjunction with some other work which grew out of it, was prompted by a note from L. H. Bailey, "propagated by layering, cuttings, and seed."(2)

The work on Lapageria rosea (red and pink), and L. rosea var. *albaiflora* Hook., was undertaken between 1981 and 1984 in Dunedin, New Zealand.

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The red flower seems to self pollinate and set seed unassisted during warm conditions, although the amount of fruit set and size (which I take to be indicative of effective pollination), was greatly

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SEED

The red flower seems to self pollinate and set seed unassisted during warm conditions, although the amount of fruit set and size (which I take to be indicative of effective pollination), was greatly improved by personal assistance.

Pollination and Timing. Collection of anthers proved to be the easiest method, collecting only those anthers from which the pollen was noticeably beginning to shed easily. This was taken as a sign of readiness. I also waited for a period when there would be warm, settled weather for a number of days, the reason being, I believe, that pollen tube growth and fertilization is assisted under such conditions. Pollination in the cold seemed to reflect this theory with often less fruit set, and those which set were of an inferior size and atypical shape.

Stigma receptivity. It was noticed that the optimum time for fertilization seemed to coincide with stigma receptivity. This I took to be when the stigma appeared to swell slightly and a clear sticky secretion appeared. This appeared to be reflected subsequently also by fruit set, as stigmas that were pollinated, which had not exhibited the secretion, showed a corresponding lack of fruit set or incomplete fertilization. Thereafter I assumed this was the case.

Methods. In applying pollen a small paint brush (camel hair) was used but, prior to dabbing the pollen on, where possible the flower and stigma were warmed by holding the flower in my hand and exhaling into it, and more importantly on to the stigma for 30 to 60 seconds. Then the pollen was applied. When the stigma was well covered the warming was repeated; this I dubbed "the Hot Breath Technique". In warmer districts this may not be needed.

Fruit harvest. Fruit was harvested after taking up to nine months or more to mature. Size and colour were indicative of ripeness. Generally the fruit began to lighten as they ripened. Ripe fruits were generally 50 mm long when picked.

Fruit processing and seed sowing. Immediately after picking, ripe fruit was opened over a fine sieve and washed, removing skin and pulp; seed was then sown in a John Innes seed mix. I used clay pans, plastic trays, and seed boxes to sow in, depending on volume and container availability. Terrazole fungicide was included in the mix.

Seed was covered by 1 to 2 times its own thickness with soil and tamped flat, then covered with a single layer of washed quarry dust, watered in with a fine nozzle and placed on a hot bench at 20°C, then covered with glass. On another occasion I used washed river sand to cover the soil mix. Seed was kept very moist until germination, then watered as required. Germination began four to five weeks after sowing and was usually complete in 12 weeks. Sowing was undertaken in 1981, '82, '83 and '84, and in some years a number of sowings took place. Germination percentages averaged 90%. In 1982, when some seed was sown in a cold frame, erratic germination took place over four to seven months and a lot of seed decayed. Germination was approximately 20%. I also found an old fruit which had shrivelled and shrunk considerably and sowed the seed on the hot bench. Germination was only 5%.

Recently I found a Thompson and Morgan catalogue (8) which recommended to soak old seed for three days, changing the water three to five times per day.

The pink flower seemed to self pollinate only intermittently when unassisted, but with my 'Hot Breath Technique' pollination was much improved and easy.

The myth of the white. The white-flowered cultivar leaves me still somewhat confused. Word of mouth and Aldworth (1) states the need to be cross-pollinated from a different white flowered plant. This I was not able to do with another white plant due to the unavailability.

I was seemingly able to effect pollination on the white plant with its own pollen using the dreaded "technique" on tagged flowers. Anthers were emasculated and pollen was taken from the resulting pool. Isolation of flowers after pollination was not done due to public location. The red-flowering plants were some distance away and no great insect activity was observed, hence it was assumed that red to white crosses were not occurring on the white-flowered plant I was working with.

Further work would need to be undertaken to isolate white stigmas to ensure no cross pollination took place with the red plants and that would prove the white plant I worked with was self-fertile.

A comparison would be needed to compare the white-flowered plant I used with another to compare purity. A visitor felt that the particular plant I used had a slight pinkish tinge on some flowers. Burbidge (4), says he has had white flowering plants produced from seed taken from flowers pollinated by artificial means under glass, but he does not mention pollen donors and mother plants. However he does mention reds, whites, and pinks, which seems to suggest a red/white cross. As the plant I used may be a result of a red/white cross, this may have an ability to be self fertile as is borne out by the pink.

Progeny have not flowered to date. This will help to resolve some of the conjecture.

Handling seedlings. Seedlings were potted into peat pots and polythene bags (75's), after second leaves appeared with as little root damage as possible, using an ericaceous soil mix, then grown on under cover with a minimum temperature of 12 to 15°C.

CUTTINGS

Media, containers and mist. I tried several rooting media with different proportions of shredded pine needles and sand ranging from 4 to 1, down to 1 to 1, and in reverse. Cuttings were placed on a hot bed at 15°C, 20°C, 25°C, or were unheated, with and without mist. Several containers were tested, e.g. pots, plastic, terracotta, and hygiene trays. Cuttings were placed under plastic tents on heat, or in a cold frame with a plastic tent, and without heat. The same treatments and proportions were tested with peat as a rooting medium.

Methods. I took random cuttings from plants with red and white flowers, cut with a knife early in the morning. Cuttings were placed into moist paper then into plastic bags. They were subsequently dipped in a captan/benomyl solution, then dried slightly and either hormone-dipped in 0.1%, 0.5%, or 0.8% IBA, or not dipped in hormone.

A variety of types of cuttings were taken, i.e. basal cuts, nodal, and internodal, old wood, previous years' and current wood cuttings, with and without leaf area reductions; usually 2 to 3 node cuttings, tips being pinched, though to no avail.

Leaf-bud cuttings also seemed to die readily in all seasons. In summary, no particular method gave any indication of the cuttings rooting.

During theses times I took consolation in, and was inspired by a well known Dunedin plantsman's (Mr. Chas. McLachlan) description of seeing a box of Chilean bellflower cuttings, healthy as ever with the roots emerging from the bottom in a tangled mass when he was a young man. His honesty and integrity need no vouching, yet he has no recollection of how this was attained. On leaving Dunedin and being in close proximity to good stock, I have pondered this greatly and have come to some conclusions.

Having such profuse stock, I have never used mother plants cultivated under glass, nor thought of the need to have, as they grew so well outside. Later I was to find that McMillan-Browse (7) suggests growing stock plants under glass as well as using leaf-bud cuttings, this possibly being an avenue worth further investigation. I also never used young plants and here again lies another avenue of investigation, i.e. whether juvenile cuttings root better than mature ones.

Burbidge, 1876 (4), confirmed one thing for me, that "Cuttings of *Lapageria* do not form plants readily. They root in about nine months, but it is essential that ripened growth only be selected. Insert them in boxes of sand/earth in a warm glasshouse temperature". He then goes on to say, "plant out and train near the glass". Thus I was thrilled to have this confirmation at least. They can be rooted from cuttings if the mother stock was under glass.

LAYERING

The plant often did this naturally, when stems which trailed down were covered by mulch. I did this in spring and autumn. Internodes that had been nicked produced a greater number of nodes with roots. It is important not to be too anxious in lifting and separating at internodes. When I did this a couple of times roots were well developed, but shoots were not, and it proved to be premature because when the plants were placed in peat pots they subsequently died without any further root development or shoot growth.

Layering being the traditional method of propagation and the only method of cultivar promulgation, there is quite a lot of literature from the northern hemisphere on this, with stock plants growing under glass, either in pots or in, preferably, specially prepared beds which confine the rootstock (5,7). It was suggested that strong second wood coiled around a pot, box, or bed be used.

MacSelf (6) suggests to nick the internodes and peg down firmly in either spring or autumn, then be patient as this process is notoriously slow. When ready, sever new plants from the mother plant and place them singly in small pots of light peaty soil.

MERISTEM CULTURE

In Chile there has been work done on meristem culture, particularly with plants producing white flowers which are becoming very rare in the wild.

In New Zealand I know of one group of people who are investigating this avenue of propagation, so no doubt in the not too distant future the resulting stock will be available.

CONCLUDING REMARKS

Hopefully many of the cultivars of the past can be successfully relocated and propagated.

Some of these cultivars are:

1. 'Alba', pure white and very chaste. (6)
2. 'Ilseman', larger flowered, more vigorous, brighter and more freely flowering. (5)
3. 'Nash Court', soft pink, slightly marbled flowers, [1st Class Cert, RHS, 1884. (1)]
4. 'Rubra', red. (6)
5. 'Splendens', rich rose. (6)
6. 'Superba', rich brilliant crimson. (6)
7. 'Warnham Court', rosy red, mottled with greyish white, [1st Class Cert, RHS, 1897. (9)]

In parting, imagine Dr. Wilfred Fox, who when travelling in Chile in 1932 found a form of *Lapageria* where the flowers were striped lengthways with crimson (3) and had not been introduced into cultivation.

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PROPAGATION OF HYDROPONICALLY-GROWN LETTUCE

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Abstract. Hydroponically-grown Butterhead-type lettuce is propagated from pelleted seed. Cultivars are selected for superior growth and yield under the environmental conditions available as well as the marketability of the finished product. Seed is sown in mineral wool starter cubes and germinated in a dark, temperature and humidity-controlled chamber. Seedlings are grown under supplemental light until large enough to transplant to gutters where they are grown to harvestable size. The nutrient film technique (NFT) of hydroponics is employed during the grow-out phase.

INTRODUCTION

After a year of pilot production in about 5,000 square meters of greenhouse, the Weyerhaeuser Company entered commercial production of hydroponically-grown lettuce in October, 1984. About three hectares of double-poly greenhouses in central Virginia produce five to seven million heads of Butterhead-type lettuce annually. Known as Waterfield Farms, the facility is located within 300 kilometers of several major population centers including Washington, D.C., Baltimore, and Philadelphia.

[1] Waterfield Farms is a division of the Weyerhaeuser Company, Tacoma, Washington, 98477

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The process uses the nutrient film technique (NFT) in which the roots are continuously wetted by a flowing film of nutrient solution (1).

PRODUCTION FACILITY

A single 27,000 square meter greenhouse is sub-divided into 112 bays: three for propagation, twelve for juvenile growth, 95 for growing-out to harvest, and two "transport" bays for crop movement. Each grow-out bay has a capacity for about 5,500 heads. The roof sections are air-inflated, double-layer polyethylene, and the walls are 16 mm doublewall acrylic panels. Cooling is provided by exhaust fans located along each sidewall and inlet vents along the central ridge of the facility. The maximum air exchange rate is one per minute. Fog and mist cooling are used during periods when the temperatures exceed 28°C. or the relative humidity drops below 60%.

The fifteen propagation and juvenile growth bays are illuminated by sodium vapor lamps. The lamps provide about 100 $\mu Mm^{-2}s^{-1}$ (approximately 700 foot-candles) of supplemental light.

Liquid carbon dioxide is injected during daylight hours to maintain 1,000 ppm whenever the vents are less than 15% open.

On-site wells provide the daily need of 40,000 liters of water.

A unique feature is the heating method. A recompression station for a transcontinental natural-gas pipeline is located half a kilometer away. Water from heat exchangers in the compressor engine exhaust is piped to the greenhouse where it is circulated through the concrete floor and back to the compressor station. It is no coincidence that the demand for greenhouse heating corresponds with demand for natural gas in the populous northeastern United States.

About 3,000 m^2 of attached "headhouse" supports sowing, transplanting, solution preparation, harvesting, packing, shipping, storage, and mechanical systems.

CULTIVAR SELECTION

In the United States, by far the most common lettuce is variously called 'Crisphead' or 'Iceberg' lettuce. Field-grown on large acreage, mostly in California and Arizona, this cultivar ships well to domestic and foreign markets. Commercial quantities are not commonly grown in greenhouses in the United States and none, to our knowledge, hydroponically.

Romaine or cos lettuces are probably second in popularity and, like Iceberg, are predominantly field-grown.

Leaf lettuces, both in green and red cultivars, are enjoying increased popularity, possibly enhanced by the increasing popularity of salad bars. Some cultivars do well in hydroponic production but often are slower growing, require more space, and have a tendency toward necrosis of the leaf margins (tip burn) in greenhouse environments. Their high center of gravity sometimes causes toppling in hydroponic systems where the roots are not firmly anchored.

Butterhead types are well suited for hydroponic growing. They are popular as salad and sandwich greens and as bedding for cold appetizers and entrees. Their low, compact form lends stability in soilless culture. The mature heads handle, pack, and ship well with little damage.

The Dutch are recognized experts in breeding vegetables for greenhouse growing. They have done a remarkable job of introducing lettuce cultivars well suited to hydroponic production (2). Form, color, taste, and shelflife after purchase are selection factors especially important to the consumer. Handling characteristics and storage life are factors important to the shipper, wholesaler, and retailer. Yield, growth rate, space requirements, disease resistance, tolerance to environmental extremes, and resistance to premature bolting are among the selection factors important to the grower (4).

Dutch cultivars are selected which have proven best for the particular time of year. For winter production 'Salina' is particularly well suited. For spring and summer 'Sitonia' is more tolerant to high temperatures, higher light, and longer days without injury or bolting. 'Ostinata' is tolerant to a wide range of conditions and is the cultivar of choice for year-round production.

SEED

Untreated seed, having a minimum germination value of 90%, is purchased from United States distributors of Dutch breeder/producers. Shipment is made directly from the seed supplier to a processor in California where it is coated with a hard, spherical pellet of about 4 to 5 mm diameter.

The principal advantage of pelletizing is to simplify the sowing process. Pelleted seed is protected from mechanical injury, easily singulated, and readily handled by a variety of precision seeders including vacuum seeders. The size, color, and shape makes inspection of sowing quality much easier.

Pelletized seed costs almost twice that of raw seed, and there is the potential for impeding germination by oxygen deprivation or by physically interfering with emergence (5). The processor claims, however, that germination and emergence is actually enhanced by the pelletizing process. Production performance tends to support these claims. The details of seed pelletizing are proprietary to the processor, but it is known that soaking in a solution of kinetin enhances lettuce seed germination at elevated temperatures (6).

Soaking for several hours in 0.5% thiourea solution and stratification at low temperature may also overcome high temperature inhibition of lettuce seed germination (3.)

Oxygen deprivation is minimized by compounding the mineral coating in such a way that the pellet splits open upon imbibing water, thus exposing the seed prior to germination (5).

A fungicide, such as Thiram, is incorporated to counteract potential seed diseases.

PRODUCTION SEQUENCE

The process starts with the mechanical sowing of pelletized seed into mineral wool starter cubes. A Hamilton seeder places one pelletized seed into the dimpled cavity of each starter cube with greater than 90% accuracy. Cubes are in units of 200, 25 mm on center and 30 mm thick. Each unit is contained in a 0.3 × 0.6 m nursery flat and 21 flats fill a 2 m × 2 m ABS flood tray. An oversow factor of about 20% allows for fall-down during propagation and culling during transplanting.

The trays are watered to capacity and placed in a dark germination chamber for two or three days. The humidity is close to 100% and the temperature is maintained at 18 to 21°C. Upon leaving the germinator, the pellets have split and softened.

The trays are then placed in the propagation area in rail-supported, castered frames holding two trays. They are covered with plastic netting to discourage birds and rodents that invariably find their way into the house. Residence time in propagation is ten days (14 in winter) during which the seedlings are sub-irrigated with nutrient solution. Temperatures are held as close as possible to 25°C. Supplemental lighting is provided from 4:00 p.m. to 4:00 a.m. from 1 October to mid-February, and on cloudy days when the ambient light drops below 170 $\mu Mm^{-2}s^{-1}$ (about 1200 foot-candles).

After several true leaves have formed, the starter cubes are separated and respaced. A special "juvenile" tray with cavities, 60 mm on center, holds the starter cubes. The trays are white on top to reflect light and heat, and black on the underside to block out light, thus discouraging algae. The seedlings are sub-irrigated with a dilute nutrient solution via 5 mm slots in each cavity.

When the seedlings are about 50 mm in diameter, the movable tables are returned to the headhouse for transplanting.

Management of the propagation, juvenile, and transplanting operations is most critical. Weak or damaged seedlings become source-points for a variety of infections that can then spread to the surrounding crop. Thus, about 10–20% of the starter blocks are culled out during juvenile respacing and transplanting. The remaining vigorous seedlings are transplanted to 2 × 4 m growing frames with gutters spaced 180 mm on center. A perforated ABS cover provides support for the individual plants. Filled growing frames are conveyed to their appropriate location on rails down and across the house.

A modified Hoaglund's nutrient solution is prepared in a battery of mix tanks from which it is pumped to distribution headers along each row of gutters. Excess solution is collected, strained, and returned to the reservoir tank. The addition of make-up water and nutrients is automatically controlled.

Residence time on the growing tables varies with the season from three weeks in the summer to six weeks mid-winter. Crops are started in such a way as to maintain a nearly constant daily production.

The frames of finished crop are returned to the headhouse packing area. The covers, now holding the mature heads, are separated from the gutters. The heads are cut from the root cube, sorted, graded, individually packaged, and packed into corrugated shipping containers. Cases of lettuce are rapidly cooled in a vacuum cooler and loaded into refrigerated trucks for delivery, usually to wholesale warehouses or the distribution warehouses of major grocery chains.

The gutters and covers are thoroughly cleaned and sterilized with scalding water and chlorine solution in preparation for the next crop of transplants.

SUMMARY

There are several keys to satisfactory germination of lettuce seed for commercial hydroponic production. These may apply as well to greenhouse soil culture using transplants.

Cultivar Selection: Select cultivars of proven performance under local conditions. Run small test crops before making a major commitment.

Seed Quality: Purchase only pretested and certified seed from reliable suppliers.

Pretreatment: While substantially increasing seed costs, pelletizing has shown overall benefits.

Propagation Environment: Within practical limits, control light, temperature, and ventilation to near optimum. Be alert to nutrient stress and predation by insects, birds, rodents, or disease.

Sanitation: While it is difficult to maintain a sanitized workplace, a dedicated effort must be made toward that end. *Botrytis*, *Cercospora* leaf spot, *Pythium*, and *Rhizoctonia* have occurred when hygiene practices are below standard. Removing all plant debris—leaves, roots, dead plants, even dried algae—is essential since all of these tissues provide food sources for fungal and bacterial growth.

Profitable production depends heavily on good seed and careful attention to the propagation phase.

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1987 NEW ZEALAND PLANT VARIETY RIGHTS ACT

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Recent legislation has been introduced in New Zealand for the further protection of new plant varieties. The legislation, under the name of the 1987 PLANT VARIETY RIGHTS ACT, is along similar lines of other intellectual property acts for patents, designs, and trade marks.

That Plant Variety Rights are viewed in the same manner (in legislation at least) as patents, is important in a commercial atmosphere. New plant varieties should be viewed as any other product, the development of which incorporates a large amount of time, effort and money. As with new products it is essential that the developer recovers his investment by obtaining sole rights to the production, marketing, and licencing of the product and, perhaps, obtaining a trade mark for the product.

There are of course differences between plants and "standard inventions". Standard inventions do not reproduce themselves, nor do they continually produce saleable merchandise (e.g. fruit, flowers). It is because of these differences that a separate act was

[1] Patent Attorneys

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devised to give protection to new plant varieties.

A successful applicant under 1987 Plant Variety Rights Act will gain the exclusive right to:

1) Produce for sale any reproductive material
2) Sell any reproductive material
3) Propagate for commercial production produce
4) Authorise anyone to do the above.

These rights last for 23 years for woody plants and 20 years for other plants.

The above rights allow the applicant to commercially exploit the new variety; however, anyone can propagate, grow, or use the new variety for non-commercial purposes. This means the person can propagate a protected variety for his or her own use but cannot sell the propagated plant or produce, such as fruit or flowers, from the propagated plant.

Furthermore, provided the protected variety is not used repeatedly, anyone can hybridise, produce or sell a new variety derived from the protected variety. The term "used repeatedly" has not yet been tried in the courts in New Zealand, therefore, there is no legal definition of this term.

There are certain criteria to be met before anyone can apply for Plant Variety Rights. The first criteria is that the applicant has to be *either the owner, assignee, agent, or personal representative of the* owner.

The variety for which protection is applied for must be "new". The definition of "new" is two-fold.

1) The variety must not have been for sale in New Zealand for more than 12 months before the application is made.
2) For woody plants the variety must not have been for sale overseas for more than six years before application. For non-woody plants this period is 4 years.

As with all criteria there are exceptions to the above rules, therefore if a potential applicant for Plant Variety Rights is concerned about the newness or novelty of his variety he should first contact a patent attorney who could advise him.

The variety applied for must be distinct, that is distinguishable by one or more characteristics over any other variety. This is generally ascertained by the applicant filling out a questionnaire relating to the particular characteristics of the plant species.

The variety must be homogeneous and regard is made to the sexual or vegetative propagation of the variety.

Finally the variety must be stable, that is true to description for reproductive cycles after repeated propagation or reproduction.

Once the plant breeder has a variety that meets the above criteria he then has a choice whether to file the application himself or obtain the services of a patent attorney. There are advantages and disadvantages for both these options. The main advantage of the applicant prosecuting the application himself is that he does not have to pay the additional costs of patent attorney fees. The advantage of having a patent attorney prosecuting the application is that they have the system set up for preparing documents, sending reminders for paying annual fees, plus knowledge of licencing and the Plant Varieties Act if any problem arises.

A number of forms are required to be filled out for the application, namely an application form, a questionnaire on the variety's characteristics and an authorization of agent if the patent attorney prepares the application. Evidence of ownership is sometimes required and details of any prior applications for rights with respect to that variety. The applicant may also deem it necessary to supply further details of the variety, perhaps giving a history of its selection and evidence by way of graphs and tables for such characteristics as fruit size and the time of crop production.

Once all the above has been filed at the Plant Varieties Office a filing date and an application number are issued. Associated with the filing date are a number of important features.

Firstly, the filing date establishes the applicant's rights, that is, the filing date gives a date from which the claims to ownership and development are based. Therefore, if a plant breeder in New Zealand files after another plant breeder's application for the same variety then the first applicant has precedence and the second applicant has no rights under the act unless it can be shown that the first breeder wasn't legally entitled.

The second important feature of the filing date is that, in contrast to most intellectual property law, legal action can be taken from this date even if rights have not been granted. However, if for some reason rights are not eventually granted, the applicant could be held for damages resulting from the legal action taken.

The third important feature is a convention period within which the applicant may file overseas. There is an international agreement, UPOV, which states despite any criteria as to novelty or newness in member countries, an application overseas within 12 months of the first application is actually back-dated to the first application date. For instance if the New Zealand filing date is in February and the New Zealand applicant files in December in the United States, then his application is actually back-dated to the New Zealand date in February that year. Therefore this convention period forestalls others from taking a protected variety from one country and exploiting it in another that the applicant wishes to eventually file in.

In order to determine whether the variety complies with the criteria discussed before, the variety must be examined. Examination is conducted over a growing season and for this purpose viable seeds should be supplied for agricultural, vegetable and herbage crops and access to ornamentals, forest and fruit trees by MAF

(Ministry of Agriculture and Fisheries) Officers is required. Therefore, depending on the variety being protected, the examination period can be from as little as six months up to 18 months.

If the results of the examination are satisfactory and the application is accepted then details of the application are published in the Plant Variety Rights Journal. If after three months from publication, there are no objections, then a grant of rights is given.

The grant of rights is no use to the plant breeder unless he can attain commercial advantage from it. There are a number of ways that the breeder can attain commercial benefits, one being to register a trade mark for the variety. Therefore anyone wanting to sell produce under the name given to the breeder's variety (not the biological name) will have to come to an agreement with the breeder and become a registered user for that trademark. This agreement can be by way of a licencing agreement wherein the user of the trade mark will have to pay a royalty or an up-front payment for use thereof. If a person wishes to sell the produce from plants he had bought and was not a registered user then he could not use the trademark commonly associated with that variety.

The plant breeder should always consider obtaining rights overseas for his variety as markets in New Zealand are comparatively small.

For growers of a particular plant, it may be advantageous to form a co-operative. Thus arrangements with respect to trade marks and plant rights may be made more easily in the co-operative setup instead of on an individual basis.

Unless a breeder has the resources to propagate sufficient quantities of the plant material to satisfy the market he is best advised to licence his rights. Intellectual property (plant rights included) is like any other property and a licence can be viewed as being a renewable lease, whereby once the lease runs out, the owner/breeder still owns the property or rights. The licenced plant rights are similar to most licences, there can be a sign-on fee as well as royalties granted. Sign-on fees encourage the licencee to promote the variety well so as to recover the initial cost.

Despite the similarities mentioned above there are still some special factors particular to Plant Variety Rights that should be incorporated into the licence. One should ensure that a royalty is paid for all material that the variety can be easily reproduced from, cuttings, seed, and the like. There should be an inspection clause to allow the licensor to inspect facilities such as seed dressing stations, glasshouses and orchards to ensure that royalties are being paid on all reproductive matter. On termination of the agreement there should be a royalty given for each plant left with the licencee. The reason for this is that although plant variety rights prohibit people propagating for commercial production, it does not stop them from producing commercial produce for plants they already have. As with most licences it is essential to have on termination, the licenced rights remaining in the breeder's name. Furthermore most licences have a force majeur or an "acts of God" clause, and genetic mutation should be included within this. Often companies have a standard licence which they wish to employ but it is advisable for the breeder to have this inspected by an agent such as a patent attorney who knows the rights granted under the Plant Variety Rights Act and can also determine whether the licence contravenes the Fair Trading and Commerce Acts.

An applicant should be aware that there can be obstacles to obtaining a grant of rights. Four such obstacles are convention applications, opposition, infringement, and compulsory licences.

If someone overseas developed independently the same variety as a breeder in New Zealand, and filed a convention application that back-dated before the New Zealand breeder's application, then they have precedence over the New Zealand breeder. This is a similar situation to that discussed previously with a New Zealander filing a convention application in the United States.

The 1987 Plant Variety Rights Act has similar sections as those in the Patent Act whereby third parties can oppose granting of plant variety rights to an applicant. The grounds of opposition can be that the applicant is not the owner of the variety, or that the variety is not new, distinct, stable or homogeneous. Publication of the application after acceptance in the Plant Variety Rights Journal is a means of notifying the public so that they can have the opportunity to object to the grant being made. In some cases objections may be made after grant on the same grounds.

If after three years from the date of grant, the breeder who has rights and has not ensured that the variety had been supplied in reasonable quality, quantity or price to the public, then anyone else can apply for a compulsory licence. This means that the breeder has to licence rights to that person at a royalty that is considered reasonable by the Commissioner, the person in charge of administering the act.

The final thing that can go wrong is infringement of your rights. An act of infringement is any act that breaches the exclusive rights granted and this includes importation and selling other plants under the protected variety's name. However the variety must be indicated to be protected or have protection applied for, so that the applicant may retrieve damages caused by the infringement. To decide the remedies available to the plaintiff (i.e. the applicant), the court takes into account the damages incurred, profits gained by the defendant and the flagrancy of the act. Being able to legally protect a variety against acts of infringement is the main reason for obtaining Plant Variety Rights.

In conclusion the 1987 Plant Varieties Act is a comprehensive act and, if used properly, can be a valuable commercial tool.

SELECTION AND PROPAGATION OF NEW ZEALAND NATIVE PLANTS FOR AUSTRALIA AND NEW ZEALAND

GRAEME C. PLATT

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Platt's Nursery is a native plant nursery growing the widest range of New Zealand native plants possible. This material is selected from the length and breadth of New Zealand and our many Offshore Islands. In accordance with our conservation policy, and because many of our plants are on the critically endangered list, we do not remove any plants from the wild for resale—only seeds and cuttings. We do take the odd plant for experimental or stock bed use. However, this is very rarely ever necessary. Many of the plants grown at Platt's were the first to be introduced into cultivation by any nursery.

We are now in a position to be able to sell all we can produce, including many plants that only a short while ago were either despised as weeds or never considered as suitable plant material for amenity horticulture. The public seek us out from all over the country, and increasingly from overseas. We do not advertise, but do carry out some direct promotion by giving talks to local gardening circles, conservation groups, and service clubs; also, stands at local trade shows and fairs have been very successful. Unfortunately, we are not able to be involved in mail order, as this is uneconomic, and we often have to leave many letters unanswered from all over the world from people wanting particular plants or information.

After visiting a large number of nurseries throughout New Zealand and a few in Australia, I am heartened by the increasing number of New Zealand plants being produced. However, my enthusiasm for quantity is not matched with that of quality. A recent survey I carried out in Auckland's garden centres confirmed that not less than 50% of all New Zealand native plants sold were variegated freaks, mutant deviations and, in some cases, virus-infested runts. One major retail outlet had 80% mutant deviations, and only 20% species. I was rather amused to be told by this group's purchasing manager that the sale of native plants was declining—a situation that did not surprise me, considering the quality of stock offered. I am delighted the gardening public, farmers, and city parks personnel are starting to reject these poor quality deviations, which have become the norm in native plant sales.

Many gardeners and native plant enthusiasts have persistently made the claim that New Zealand plants are somehow different and harder to grow than many of the exotic plants with which they have had experience. This is a contention I have always disputed. How could a New Zealand plant be any different from any other nation's?

However, I have now isolated four answers to this question and must concede, in some cases, they are correct.

1. Those exotic plants grown in New Zealand were already successful in their country of origin whereas those unsuccessful species were never introduced into cultivation.
2. Most unsuccessful New Zealand plants are rain-forest plants, or have other very specific climatic or physiological limitations.
3. Those native plants that are successful are, for the most part, not rain-forest plants.
4. Species that have been consistently unsuccessful have not been selected from suitable genetic stock.

RAIN FOREST PLANTS

It was our interest in kauri trees (*Agathis australis*) that finally opened my eyes to the essential requirements of rain-forest plants. How is it possible for these magnificent giants of a thousand years or more to grow so well, and only 50 yards away in a domestic garden to do so pitifully. Everything is the same—or is it? The answer is very simple. Rain-forest plants do not grow in soil. Rain-forest plants are dependent on the organic litter that builds up on the forest floor from the falling leaves, bark, twigs, branches, dead fallen trees, and decomposing animal life; such as worms, bugs, insects, birds, etc. This organic litter is important for root development and nutrient uptake, and in many cases the habitat of essential mycorrhizal fungi. These symbiotic fungi are the essential step in translocating nutrients from the organic litter into the plant roots.

As a result of these observations, we now recommend that growers of native plants never plant them in soil, but on the top of cultivated soil covered with a bed of organic mulch to the depth of the nursery container (Figure 1). The results of this procedure are dramatic. A number of species are now growing up to ten times faster than what we accepted as normal. Where we once expected 6 in. growth per annum, we can now get 36 in. or more. These specifically include all our native soft-wood conifers and podocarps, and the broad-leafed terminal trees. Further study of the natural order of vegetative progression of a rain-forest was essential to understand the specific requirements of these plants, and has been most enlightening, explaining the different cultural needs of New Zealand plants.

We have been able to isolate six separate stages in the development of a natural rain-forest (Table 1, Figure 2). It is important, however, to remember that at times some stages can be completely bypassed—also, the introduction of foreign weed and animal species has further complicated natural forest development.

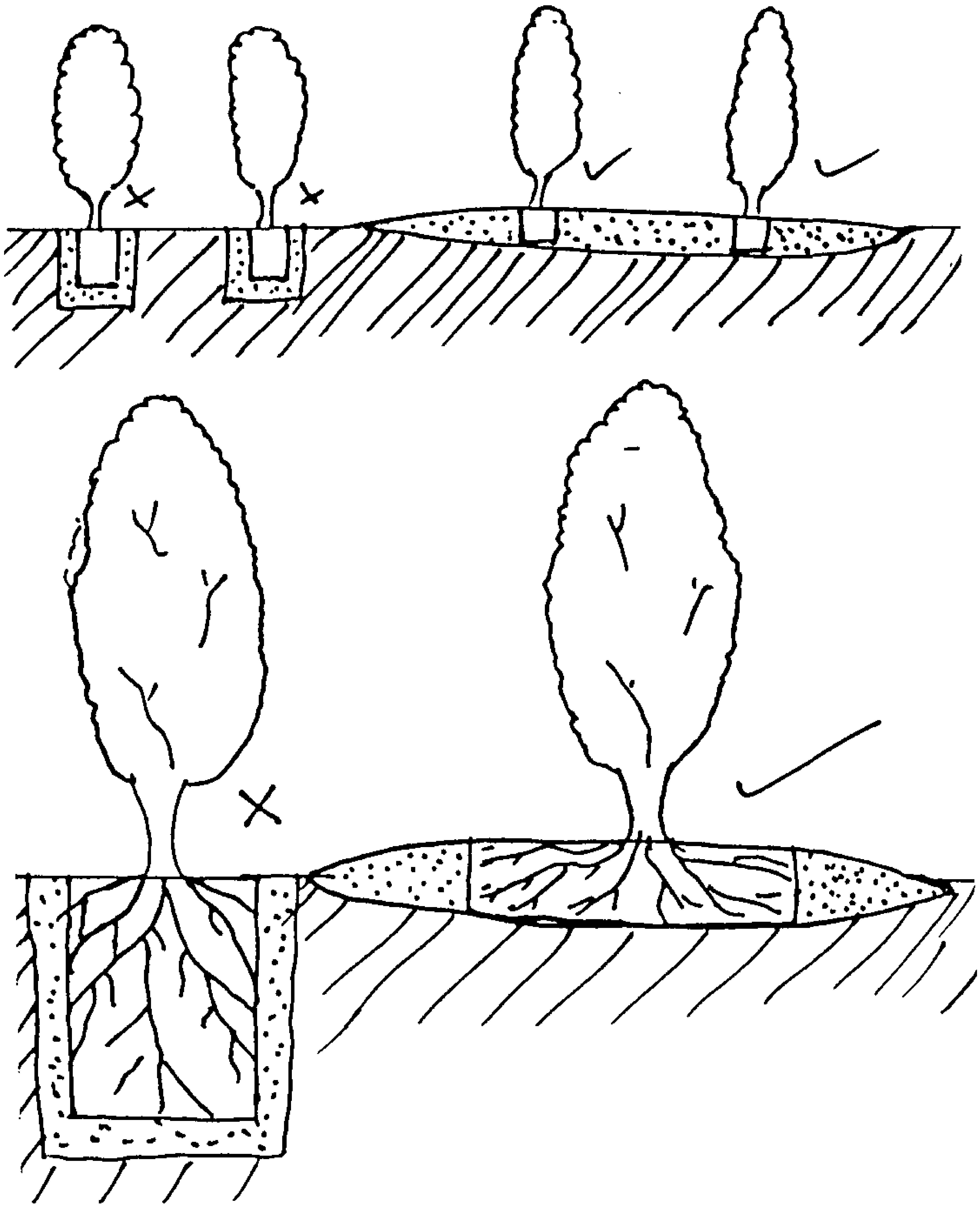

Figure 1. Recommended procedure for planting and growing New Zealand rain-forest plants.

Above. Small trees. *Left.* Incorrect. *Right.* Correct.

Below. Large trees. *Left.* Incorrect. *Right.* Correct.

Large trees are best grown in flat containers and should not be planted in holes but in a cultivated bed of humus on the surface of the ground.

Table 1. Natural Order of Vegetative Progression of New Zealand Rain-forest (Based on seed germination and species establishment dictated by favourable conditions created by the preceding stage.)

STAGES					
1. Vegetation free	2. Primary herbaceous colonization	3. Secondary growth	4. Primary broad-leaved forest	5. Mature softwood rain-forest	6. Terminal hardwood decadence
			Some Typical Species		
	Under 3 ft.	3 to 20 ft.	30 ft.	80 to 200 ft.	50 to 100 ft.
	Carex	*Brachyglottis*	*Aristotelia*	*Agathis*	*Alectryon*
	Celmisia	*Coprosma*	*Brachyglottis*	*Dacrycarpus*	*Beilschmiedia*
	Chionochloa	*Cordyline*	*Coprosma*	*Dacrydium*	*Corynocarpus*
	Cotula	*Coriaria*	*Cyathea*	*Libocedrus*	*Dysoxylum*
	Epilobium	*Corokia*	*Dicksonia*	*Podocarpus*	*Elaeocarpus*
	Festuca	*Cortaderia*	*Griselinia*	*Prumnopitys*	*Hedycarya*
	Pimelia	*Gahnia*	*Hoheria*		*Litsea*
	Raoulia	*Hebe*	*Knightia*		*Nestegis*
	Scleranthus	*Kunzea*	*Melicytus*		*Rhopalostylis*
		Leptospermum	*Myrsine*		*Vitex*
		**Metrosideros*	*Olearia*		
		**Nothofagus*	*Pittosporum*		
		Phormium	*Pseudopanax*		
		Pomaderris	*Sophora*		
		Sophora			
			Usual Depth of Organic Litter		
Nil	0 to 4 in.	0 to 12 in.	8 to 12 in.	½ to 6 ft.	1 ft. to 6 ft.
			Light		
	Intolerant of shade	Intolerant of shade	Semi-tolerant of shade	Juvenile tolerant of light shade	Juvenile very intolerant to light
			Wind		
	Very wind tolerant	Wind tolerant	Reasonably wind tolerant	Intolerant of wind	Intolerant of wind

*Form forests in their own right

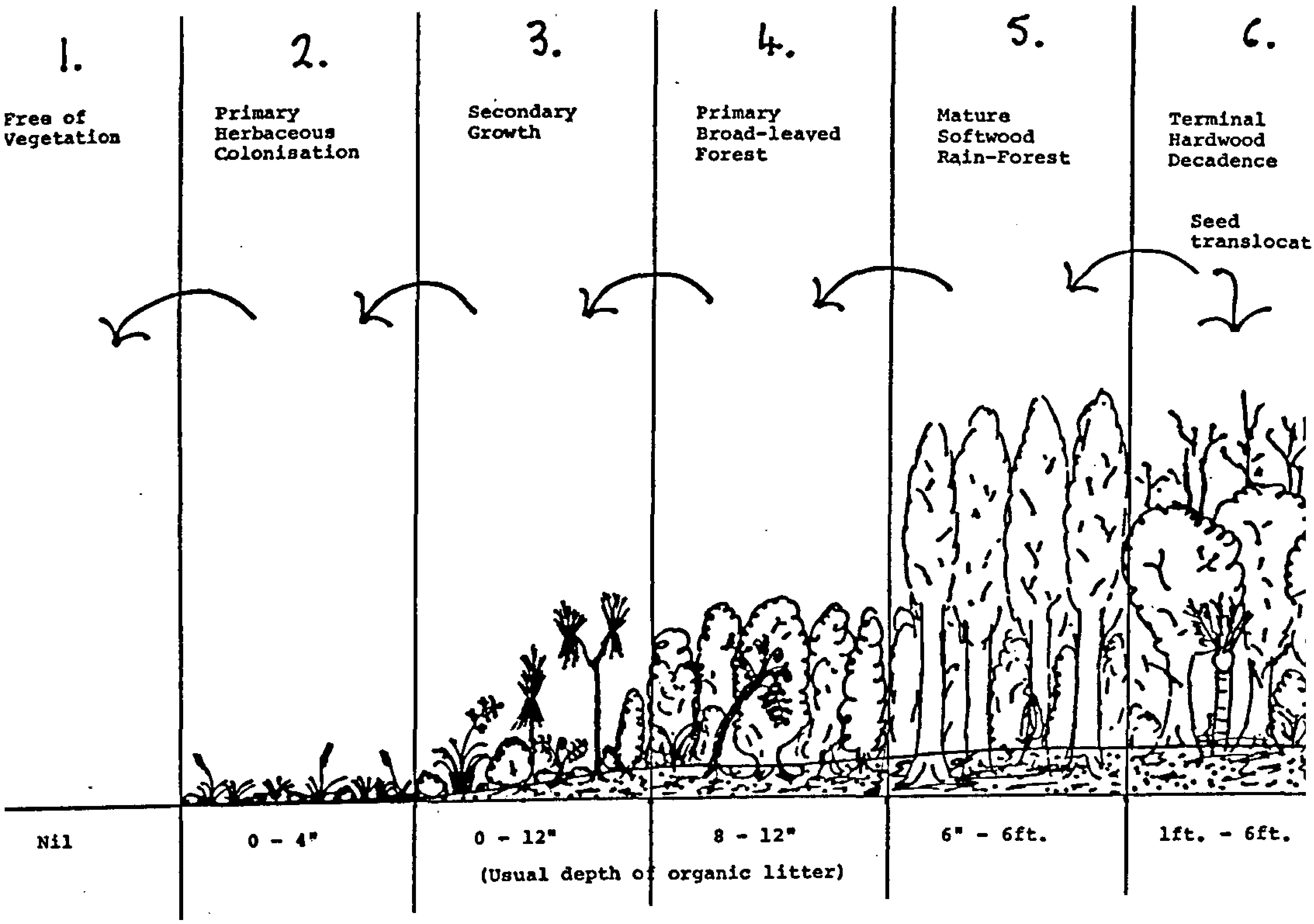

Figure 2. Natural order of vegetative progression of New Zealand rain-forest plants.

Stage 1. (Vegetation free). Stage 1 is devoid of any natural vegetation. New Zealand does not have any real deserts. However, small areas are devoid of vegetation, such as mobile coastal sand-dunes; glacial moraine; areas of high natural mineral toxicity; impervious rock; and the high altitude nival zone. The major causes of natural vegetative destruction and clearance are fires, land slips as well as avalanches, wind storms and volcanic ash showers. These areas may be very rapidly re-colonized.

Stage 2. (Primary herbaceous colonization). These first colonizers are plants that flourish in sand, gravel, shattered rock, and poor clays including all manner of mosses, lichens, small creeping herbs, mat plants, and small grasses. These plants are basically herbaceous. The general trend is that they are plants with seeds which are wind-distributed, and these seeds keep fairly well. Seed germination is enhanced with light. These species are intolerant of shade.

Stage 3. (Secondary growth). Plants of this Stage overtake Stage 2, and will flourish in a wide range of soil types and conditions. Insects and birds play a part in the pollination of this group. Seeds generally keep reasonably well. Light is required for seed germination of many of these species. Plants, for the most part, are intolerant of shady conditions.

Stage 4. (Primary broad-leaved forest). Stage 4 again supersedes the other two growth stages, and this vegetation is made up of a very diverse selection of large shrubs and small hard-wood trees, which are very tolerant to a wide range of growing conditions; such as wind, poor soil, frosts, etc. The bulk of our most successful New Zealand plants in cultivation come from this stage. These plants are easy to grow under a wide range of conditions, and respond well to organic mulching, but it is not absolutely essential. This stage is the cover for the establishment of plants of the next stage.

Stage 5. (Mature soft-wood rain-forest). It is the Stage 5 plants which have consistently caused the most problems in cultivation. Seed from this stage have established themselves earlier under the cover of Stage 4, and the most important consideration here for the nurseryman is that these seed germinate in the humus litter now being built up. Therefore, in cultivation these plants require humus and shelter from wind to establish well. Light shade is only required in the juvenile growth phase. These soft-woods include all of our giant trees—*Agathis, Dacrydium, Libocedrus,* and the podocarps. Seed as a rule keeps badly and must be sown fresh. Soil pH drops with the build-up of humus from the creation of humic acid, and the resultant podzolisation destroys the forest. None of these trees can tolerate their root zone drying out.

Stage 6. (Terminal hard-wood decadence). Stage 6 is the final and terminally decadent stage of the rain-forest. Stage 5 plants cannot re-establish themselves under themselves, because their seed do not germinate in dense shade. Therefore, Stage 6 plants take over. These are our broad-leaved hardwoods, and some are the most troublesome for the cultivator. These seeds are often large, such as in *Corynocarpus laevigatus, Beilschmiedia tawa,* and taraire. These crash to the forest floor or are spread by birds, whereupon they germinate in dense shade in association with organic litter that can be up to 6 feet deep. Many of these Stage 6 trees are much admired but do very poorly in cultivation—always because their basic requirements are not understood.

After Stage 6 you return to Stage 1—i.e., terminal decadence can be replaced by destruction, and the process starts all over again.

Having established that plants are not created equal, and have a very specific place in the natural order of progression, there is a factor which completely contradicts this natural order.

GENETIC DIVERSITY

Inherent in every species is a broad genetic diversity, thereby allowing the species to adapt to its ever-changing circumstance. This genetic diversity is passed on in the plant's seed. We have been absolutely astonished at how wide this diversity can be. Because most New Zealanders live in an area with a reasonable climate, they, for the most part, do not realize just how severe our climate can be in the remote areas where few people live, and where many of our most interesting plants still survive. This isolation is also the reason why the natural habitat of these plants has not been destroyed.

RAINFALL

The rainfall in Fiordland can, in some areas, be between 200 and 300 inches per year, and 36 inches in 24 hours is often quoted as being heavy rain at places along the Milford Track. Mt. Egmont has recorded 70 in. in one month, and many areas record a 1 in. per hour for 24 hours. Large areas of New Zealand mountains receive over 100 in. per year. Is it any wonder that plant material taken from these areas fail in suburban gardens, which in the summer may receive as little rain as 1 in. in 3 months, and a total for the year of only 35 in.?

Some of our mountain valleys are full of glacial ice, and have been that way since before the last Ice Age. These valleys may receive a frost most nights of the year. Many of you will have seen the beautiful mountain river valleys that are free of trees on the river flats and the level ground. That is because the frosts are so severe the trees cannot grow. However, the relatively warmer mountainsides will be covered with trees until you reach the treeline higher up. Plants taken from these cold areas do not flourish in a warm, sub-tropical city that receives, maybe, one or two mild morning frosts per year. Other areas receive very low rainfall—below 10 in. for Central Otago.

This very diverse climate—with its winds, its frosts, and its rain—and the extreme geological diversity of New Zealand, have further enhanced the genetic diversity of our plant species. By selecting seeds from the correct site, many species that I had considered impossible to grow are now flourishing in our climate. Nature has already done the selection for us. All the propagator has to do, if he wishes to grow a species, is to visit an area with the correct climatic factors and select seed. Of the countless billions of seed that are produced every year, only that which is fit for the specific site will grow, and therein lies the answer to the selection of suitable plant material.

Leaf shape and size are the most obvious examples of genetic diversity. Larger flowers and different flowering times are also conspicuous. The larger-leafed variants come from the warmer sites.

Our Offshore Islands have very large leaves compared with colder mainland locations. However, it is the invisible differences which are the most interesting—plants that are tolerant to insects; plants that are more tolerant to wind, to pathogenic fungi, to higher light, to alkaline or acid conditions, to heavy frosts, to wetter ground, or to the browsing of noxious animals. (New Zealand had no browsing animals, but it is interesting to note that the Australian bushy-tailed possum is wiping out some plants, but there are members of the same species that they leave untouched. These untouched ones must be unpalatable to them.)

With *Pseudopanax discolor*—a natural shade, under-storey plant, that we were never able to get to grow in cultivation while we were selecting material from its natural habitat—we finally selected material growing on a hot, sunny, rocky hillside, and we found that plants taken from this source are now flourishing in cultivation. These plants were only 100 yards from the forest shade-loving types.

Metrosideros parkinsonii is a shrubby small tree that grows at an altitude over 2,000 feet in cool, misty, rainy mountaintops. Our first efforts to grow this plant were a total failure, until we again selected seed from the driest, rockiest site, which was not typical of its natural habitat, and we now have it thriving in the nursery. Seed taken from this nursery plant now grow so well that I often wonder why I had such despair in trying to cultivate this plant.

Each species has its inherent diversity, so by collecting the correct seed type for the conditions where the plants are to be located will ensure good results. This selection of the correct plant material for your site can be further assisted by collecting very large amounts of seed then, after planting, subject them to a rigorous selection process. Use no fungicides or insecticides; and let the sun, the wind, and the rain do their worst. This will kill off all unsatisfactory material. The survivors are able to flourish under those conditions, so these survivors are the plants you want. We have established that many of these hitherto impossible plants can be made to flourish by this simple procedure.

SUMMARY

To summarize, in the past many New Zealand native plants have done poorly in cultivation, because of poor genetic-type and the planting of rain-forest plants in soil

1. New Zealand native plants should not be planted in soil, but in rich beds of organic humus.
2. Inherent in every species is a genetic diversity which allows us the opportunity to select a form of the species that will perform up to expectations in most conditions.

STRAWBERRY BREEDING IN NEW ZEALAND

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Pukaki Orchards Ltd
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Pukaki Orchards Ltd, through its parent company, Turners and Growers Ltd, became involved in strawberry breeding in 1982. In that year a joint agreement was made with the Crop Research Division of the Department of Scientific and Industrial Research (DSIR), Lincoln. From 1983 to 1986, 50,000 seedlings have been evaluated and 51 selections made. No cultivars have been released. Cooperating growers in the testing programme want "to run" with an 'Aiko' × 'Pajaro' selection, 'T26', and a day-neutral selection 'T30' (Fern seedling × Douglas).

STRAWBERRY ORIGINS

The cultivated strawberry, *Fragaria × ananassa Duch,* is the result of a hybridization of the two native American species; *Fragaria chiloensis* (L) Duch and *Fragaria virginiana* Duch.

A French army officer, Amédée Francois Frézier is credited with the first development of the cultivated strawberry. In 1714 he returned to Brest, France, from a foreign mission where he had seen the large fruited *Fragaria chiloensis* at Concepción, Chile. Within a few years an industry developed at Brest where Frézier's pistillate plants of *Fragaria chiloensis* were interplanted by chance with staminate plants of *Fragaria virginiana,* so that an improvement of cultivated strawberries began. Much of the improvement is a result of the last 25 years of work. Most of the successful cultivars have emanated from the University of California, Davis, programme under the direction of Dr. Royce S. Bringhurst and Victor Voth.

Active strawberry breeding programmes have also been undertaken in the Eastern U.S.A., Canada, Britain, Europe, and Japan, but none of the cultivar releases have proved adaptable to New Zealand conditions.

METHODS

Dr. Ivor Lewis from the Crop Research Division of DSIR, maintains all the parents and carries out the crossing programme in the spring in a greenhouse at Lincoln. The seeds are scarified and raised to the two-leafed stage in the greenhouse. The seedlings are then sent in January (mid-summer) to the Turners and Growers Limited Research Facility at Mangere, Auckland, planted in Root-trainers and grown-on in a shade house until field planting in April/May. The seedlings are planted on a mound covered with a black polyethylene mulch. The mounds are 750mm apart. The spacing between seedlings in the row is 250mm.

The majority of seedlings flower within 5 months of planting and are evaluated twice per week until the end of December.

Our selection criteria is for yield, taste, the aromatics of the fruit, colour, firmness, plant growth, ability to produce runners, and resistance to disease.

Propagation and Subsequent Testing. At the end of December final selections are made. All other seedlings are removed. A 100mm layer of sawdust is placed around the seedlings which then start to produce runners.

Tissue-cultured and field-grown runners are produced over the autumn. These daughter plants are used as stock in the nursery and for progeny testing. Progeny testing is carried out in a hydroponic greenhouse and at cooperating growers properties. Because strawberry yield and quality characteristics are dependent on the clone and the climate of the growing area the three grower co-operators properties are in different areas of the Auckland district.

The grower testing also evaluates new cultivars imported from overseas for chilling requirement, planting time, and planting distance. Strawberry plants have a chilling requirement similar to many deciduous fruits. Every cultivar has an optimum winter chilling requirement for best performance. If the chilling requirement is completely satisfied during the winter, a normal growth cycle occurs: leaves and flowers develop in spring, and runners are

Table 1. The chilling response of seven strawberry cultivars to 0, 15, or 30 days cool storage at 2.2°C.

Cultivar	Cool storage (days)	Weight of fruit per plant (gms)	Average berry weight
Tioga	0	537	13.33
Pajaro	0	407	20.61
Douglas	0	363	13.08
Aiko	0	275	15.90
Tioga	15	590	14.13
Pajaro	15	327	17.69
Douglas	15	368	14.55
Aiko	15	206	15.17
Tioga	30	383	12.16
Pajaro	30	325	19.22
Douglas	30	451	14.21
Aiko	30	190	13.62
T7 (Douglas × Holiday)	15	499	15.63
T8 (Holiday × Tufts)	15	332	11.99
T17 (Holiday × Douglas)	15	410	16.72
Sample SE		98	2.48

produced in summer. Weak plant growth and small, soft fruit with reduced shelf life may result from insufficient winter chilling. Excessive chilling causes poor fruit production and excessive plant growth and runnering.

Table 1 gives an example of the chilling response testing that is carried out.

SUMMARY

The success of our programme is our ability to propagate high quality plants for grower testing. Along with the breeding programme we also run a nuclear and elite plant certification scheme and distribute and sell about 60% of all strawberry plants sold in New Zealand.

DUNCAN AND DAVIES NEW ZEALAND *PSEUDOPANAX* SELECTIONS

PHILIP J. CARSON

Duncan and Davies Nurseries Ltd
Waitara Road
Brixton, Waitara

Family—ARALIACEAE—mainly a tropical family with some genera in temperate regions, e.g. *Pseudopanax*
Genus—*Pseudopanax*

OUTLINE OF THE PSEUDOPANAX SPECIES

There are approximately 20 species of this genus of which about 14 are endemic to New Zealand. Species that were previously classified in the genus *Neopanax* are now included in the genus *Pseudopanax*, which are glabrous shrubs or small trees with very variable leaves which may be simple, digitately compound or palmately lobed. The juvenile leaves of young plants often differ greatly from those of the adult.

Some of the species, particularly *Pseudopanax crassifolius* are excellent plants from a landscape point of view with a great variety of foliage type and plant form not found in any other hardy exotic trees. In other species, particularly *Pseudopanax laetus* and *P. lessonii*, the plant form is not so characteristic but they are excellent foliage plants and are very suitable for growing in pots and tubs for interior decoration or on patios and terraces.

Not all of the species are completely hardy. *P. lessonii*, *P. discolor*, and their cultivars can be somewhat tender where heavy frosts are experienced.

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All species will grow in a wide range of soil types but do best in a soil that is well drained. They grow well in an open position with plenty of air movement and in exposed coastal situations. All species will grow in various situations from full sun to partial shade.

PROPAGATION

The two methods of propagation are by seed and by cuttings.

Seed Propagation. All *Pseudopanax* species can be successfully raised from seed. At Duncan and Davies we propagate *Pseudopanax crassifolius* and *P. lessonii* from seed. These species hybridise quite freely in the wild so we get a large variation in leaf types from the seedling raised plants. This gives us the opportunity to continue selecting different forms for either their foliage type or growth habit.

After the seed is collected it is best sown when fresh. In September [spring] we pre-germinate the seed in sphagnum moss at room temperature prior to sowing which gives us a much better result than direct sowing the seed.

The seed is then sown in a seed mix containing 50% peat and 50% pumice-sand plus various elements [Table 1]. The seed trays are placed on bottom heat set at 22°C in a propagation house with the air temperature held at around 25°C. After 3 to 4 weeks from sowing the seedlings appear. Then after 6 weeks from sowing the seedlings are pricked out into 5.5 cm Maclons into a G.O.L. mix containing two-thirds composted bark and one-third bark fibremix plus various elements [Table 1]. The newly-potted seedlings are then placed in a heated house for about 1 month to re-establish with air temperature held at 25/15°C (max./min.). After they have re-established they are then placed in a shade house [50%] for the balance of the growing season.

Table 1. Components in the seed mix and growing-on-line mix [G.O.L.] per ½ cubic metre

SEED MIX		G.O.L. MIX	
50%	Peat	66.6%	Composted bark
50%	Pumice-sand	33.3%	Bark fibremix
230 gms	Nitroform	1135 gms	9 month Osmocote
455 gms	Superphosphate	230 gms	3 month Osmocote
114 gms	Potash	455 gms	Superphosphate
455 gms	Dolomite lime	680 gms	Dolomite lime
230 gms	Whiting	455 gms	Whiting
30 gms	Terrazole	30 gms	Fritted Trace Elements
40 gms	Lindane prills	300 gms	Cal Nitro
		40 gms	Lindane prills
		30 gms	Terrazole

The following spring they are planted out and grown for two growing seasons to attain a saleable grade. The saleable grade varies greatly with seedling raised plants.

Cutting Propagation. Duncan and Davies selected cultivars are all propagated by cuttings. Cuttings are taken in May from new season's growth that is firm. We usually make top cuttings about 8 cm long with 3 to 4 leaves left on the cutting. They are made as nodal cuttings and are wounded on one side. The cuttings are dipped in 0.8% IBA powder which also contains a fungicide (Thiram).

The cuttings are set into Plixie 54's into a propagation mix containing 3 parts sawdust, 2 parts peat, and 1 part pumice-sand to which is added 30 gms Terrazole and 500 gms 9-month Osmocote per ½ cubic metre.

The cuttings are placed on bottom heat set at 22°C and the air temperature is held at around 25°C. Root initiation usually begins after 5 to 6 weeks and they are usually well-rooted after 8 to 12 weeks. *Pseudopanax* cuttings do best in an airy environment and it is important for the high humidity conditions to be maintained for the shortest possible time. The air temperature is usually reduced to about 20°C after 6 to 8 weeks.

After 8 to 12 weeks, when well-rooted, cuttings are potted into 7 cm Maclons into the G.O.L. mix shown in Table 1. They are then placed into a heated house for 4 weeks to re-establish with the air temperature around 20°C. After re-establishment they are placed in a shade house (50%) for the balance of the growing season. The liner plants are trimmed in December/January to produce a three-bunched plant. During propagation the cuttings are sprayed every two weeks with Ailette/Captan/Lorsban and alternated with Benlate/Captan/Orthene. In the liner and field stages the plants are sprayed at three weekly intervals with a general spray programme.

The following spring the plants are planted out for two growing seasons to attain a saleable grade.

Pests and diseases. Pseudopanax plants are susceptible to the black leaf spot fungus, *Alternaria tenuissima,* which is controlled with the use of Dithane M45, Euparen, and Sportak.

The main insect pest of *Pseudopanax* is the oyster-shell scale which is controlled with Lorsban or Orthene and, with heavy infestations, they are best incorporated with an all-seasons oil.

Stock plant material. The juvenility factor plays a major part in the successful propagation of *Pseudopanax* by cuttings. With permanent stock plants they should be hard-pruned to 30 to 40 cm high every other year and lightly pruned in the alternate year. At Duncan and Davies we produce temporary stock crops in the field which we take cuttings from for 2 to 3 years and then sell the plants. In this way we are able to maintain plants in a more juvenile state which gives a higher propagation percentage.

DUNCAN AND DAVIES CULTIVARS

Duncan and Davies produce several cultivars, all of which originated at the nursery, and all are propagated by cuttings. They are as follows:

Pseudopanax 'Adiantifolius'—This is a hybrid whose parentage is probably *P. lessonii* and *P. crassifolius.* It is a strong growing cultivar with erect branches and, with its green foliage which is suggestive of *Adiantum,* it is very distinct. The true *P.* 'Adiantifolius' occurred in the wild and is now rare in cultivation. What Duncan and Davies produce as this plant is a seedling which differs by the leaves not being so thick and narrower at the base and also more deeply lobed. It is an erect shrub or small tree growing to 4m or more.

Pseudopanax 'Cyril Watson'—This cultivar belongs to the same hybrid group as P. 'Adiantifolius'. Its distinguishing features are a very compact growth habit and thick leathery deep-green leaves which are 3 to 5 lobed with short broad lobes. It makes an excellent tub plant for patios and indoor use. This cultivar was named in honour of a long-serving member of Duncan and Davies staff. It is a compact shrub growing to approximately 2 to 3 m.

Pseudopanax 'Linearifolius'—This is another hybrid between *P. lessonii* and *P. crassifolius.* However in Duncan and Davies earlier catalogues it is indicated that it is a form of *P. lessonii* from Mercury Bay. This is a fastigiate growing shrub to 3m or more. Leaves are of a dark green, mainly 5 foliolate, and individual leaflets are up to 20 cm long. It is excellent for tub culture and very tolerant of dark conditions.

Pseudopanax 'Purpureum'—This is another hybrid probably between *P. lessonii* and *P. discolor.* This is a much-branched shrub of 3 to 4m or more. The leaves are 3 to 5 foliolate on stout petioles with the leaflets 5 to 10 cm long. The foliage colour is a rich bronze purple, particularly during the colder months of the year. This cultivar is also excellent for tub culture.

Pseudopanax crassifolius 'Sabre'—This cultivar is a seedling selection of *P. crassifolius* which is faster growing and branches from a lower level. The leaves of young plants are up to 30 cm long and deflexed as in *P. crassifolius.* The foliage colour is a very dark green with an orange coloured mid rib which is very distinctive. It is an excellent plant for landscape work with a very fastigiate erect habit when young and forms a more rounded head as it matures, growing to 4 to 6m.

Pseudopanax 'Trident'—This cultivar is in the same hybrid group as *P.* 'Adiantifolius'. The leaves are of two kinds on the same plant. Those from which its cultivar name is derived are 3-lobed with the lobes all pointing forwards. It also has simple lanceolate leaves which have no lobes. As it matures the lobed leaves become fewer. Foliage color is a deep green with some bronzing in colder conditions. It is a very erect growing shrub or small tree to 3 to 4m or more in height. It is very wind hardy and tolerant of shady conditions.

Pseudopanax lessonii 'Gold Splash'—This cultivar is the most recent introduction by Duncan and Davies and was first released for sale in 1978. It appeared as a mutation which sprouted from the stump of a plant of *P. lessonii* which had been cut off at ground level in the garden of Mr. Trevor Davies, New Plymouth. Its foliage type and growth habit are the same as for the typical form of the species, leaves being 3 to 5 foliolate on stout petioles 5 to 15 cm long. It grows as a much branched shrub 3 to 4m in height. Its leaves are so heavily variegated with yellow that they appear to be all yellow with flecks and splashes of light and dark green. On older leaves the yellow tends to become more creamy. This is an excellent landscape plant and is quite suitable for tub culture.

Duncan and Davies are continually selecting for different foliage types and plant habits and these are put through a trial programme to select for ease of propagation, growth performance, pest and disease resistance, and hardiness. This programme can take several years before a plant is given a cultivar name and commercially produced.

SIGNIFICANCE OF GELLING AGENTS IN A PRODUCTION TISSUE CULTURE LABORATORY

BEVERLEY J. NAIRN

Tasman Forestry Micropropagation Laboratory
P.O. Box 149, Te Teko, Bay of Plenty

This paper gives a brief account of some experiences with gelling agents and their effect on the survival, multiplication rates, and vitrification in a production crop of micropropagated *Pinus radiata.* No attempt has been made to obtain quantitative data. Vitrification was also influenced by benzylaminoprine (BAP) concentration and other factors (1). The additives to the medium studied were Merck 2186 activated charcoal, Difco Bacto agar, Davis Bacto agar, Coast Biologicals agar (batch 950), Agarose type V, and Gelrite.

The study was undertaken to find the best combination of agar, Gelrite, and BAP to give the greatest multiplication of shoots without vitrification.

MATERIALS AND METHODS

The basic proliferation medium was modified Quoirin Le Poivre (2) with 3% commercial sugar. Gelrite is the trade name for a polysaccharide gellan gum compound produced by the bacterium *Pseudomonas.* The gum produces a mineral dependent, water clear, brittle gel at much lower concentrations than agar, making it very desirable for routine use. Gelrite is supplied by Kelco Division of Merck & Co., Kelco, San Diego, California, U.S.A. Difco Bacto agar is supplied by Difco Laboratories, Detroit, Michigan, U.S.A. Davis Bacto agar is supplied by Davis Gelatine Co., Auckland, N.Z. Coast agar is supplied by Coast Biologicals Ltd, Auckland, N.Z.

Embyros were initiated in plastic petri dishes for the first 12 weeks and were later transferred into clear polystyrene culture pots for subsequent elongation stages. Incubation conditions were 25°C by day, 19°C night temperature with a 16-hour photoperiod of 40μ Einsteins/m^2/sec using cool white fluorescent tubes as the light source.

The seedlot in use was an open pollinated 850 selection from Tasman Forestry's Te Teko seed orchard.

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The study was undertaken to find the best combination of agar, Gelrite, and BAP to give the greatest multiplication of shoots without vitrification.

MATERIALS AND METHODS

The basic proliferation medium was modified Quoirin Le Poivre (2) with 3% commercial sugar. Gelrite is the trade name for a polysaccharide gellan gum compound produced by the bacterium *Pseudomonas*. The gum produces a mineral dependent, water clear, brittle gel at much lower concentrations than agar, making it very desirable for routine use. Gelrite is supplied by Kelco Division of Merck & Co., Kelco, San Diego, California, U.S.A. Difco Bacto agar is supplied by Difco Laboratories, Detroit, Michigan, U.S.A. Davis Bacto agar is supplied by Davis Gelatine Co., Auckland, N.Z. Coast agar is supplied by Coast Biologicals Ltd, Auckland, N.Z.

Embyros were initiated in plastic petri dishes for the first 12 weeks and were later transferred into clear polystyrene culture pots for subsequent elongation stages. Incubation conditions were 25°C by day, 19°C night temperature with a 16-hour photoperiod of 40μ Einsteins/m^2/sec using cool white fluorescent tubes as the light source.

The seedlot in use was an open pollinated 850 selection from Tasman Forestry's Te Teko seed orchard.

SHOOT DEVELOPMENT AND ELONGATION

Embryos from *Pinus radiata* were extracted from sterilized seed and planted with cotyledons embedded in the medium with 5mg/l BAP and gelled with 0.8% Difco Bacto (DB) agar as described by Aitken-Christie et. al. (3). After the original shoot initiation, elongation took place on QLP medium in the absence of BAP, shoot clumps being divided each 4 to 6 weeks until fully elongated as 3cm shoots. The following observations were of 50,000 shoots, and with the exception of a few clones were seen in greater than 90% of the crop.

Good meristematic tissue was produced and developed into shoot clumps over the next 12 weeks. In the 6 to 12 months following, the shoots failed to elongate and steadily declined in health until die back was prevalent, and elongation was so slow that losses exceeded growth. (Figure 1). While other factors probably

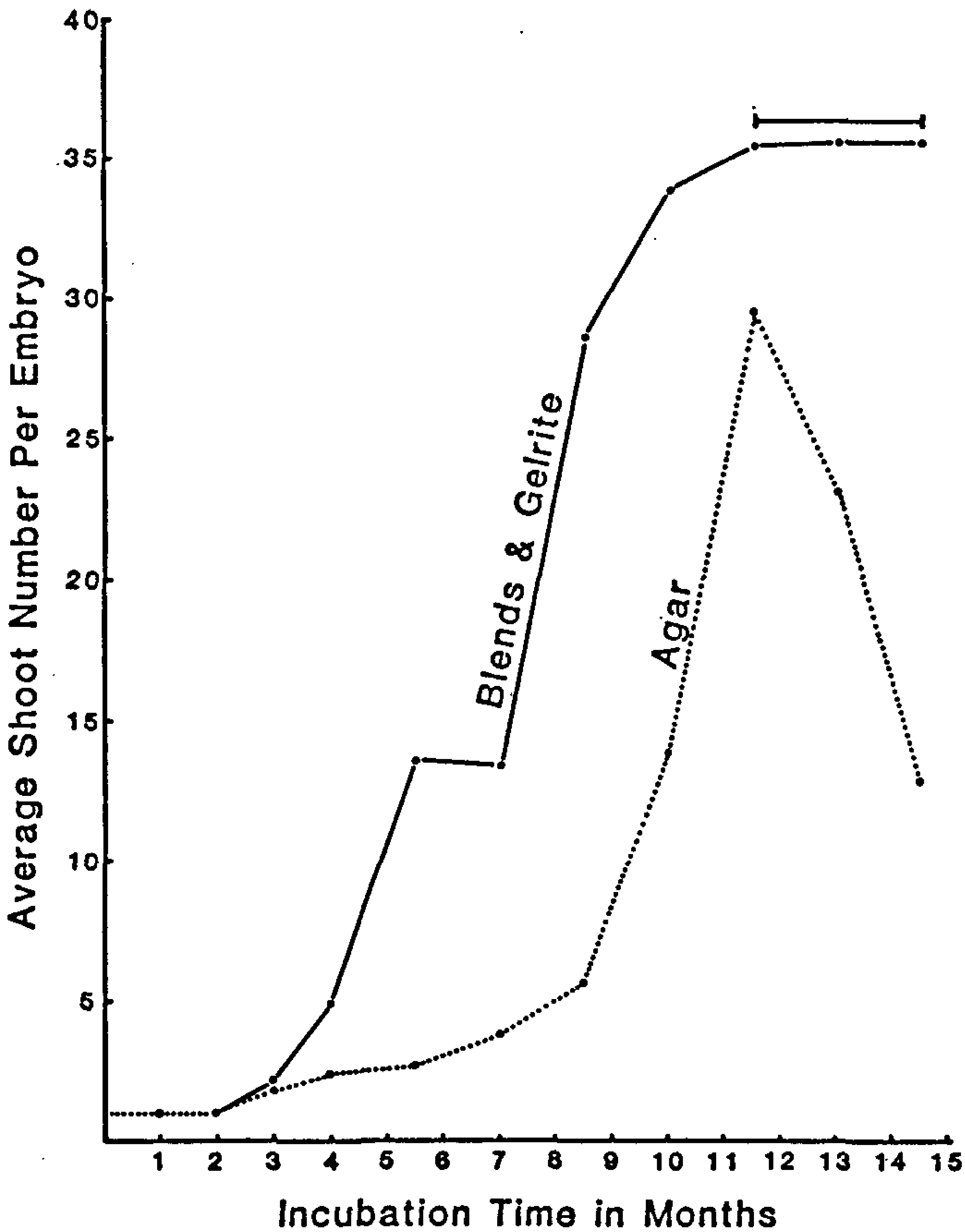

Figure 1. Growth comparison. Agar vs. Gelrite-agar blends.

had an influence, the major cause of decline proved to be continued growth on medium solidified with 0.8% DB agar. Similar medium with 5gms/l Merck activated charcoal exhibited good health and elongation. Continued growth on a charcoal-containing medium was undesirable for reason of reduced light transmission when pots were stacked and bacterial contamination which increased significantly. Medium dehydration was excluded as a major cause.

Trials showed media gelled with 2 gms/l Gelrite producing much improved growth as T. Ichi found with several species (4) (Figure 1). After 4 successive transfers shoots became vitrified. The needles became dark green, translucent, thickened, and brittle. "Vitrification" refers to these visible symptoms only, as no cytology was done. In young shoot clumps the tissue quickly became necrotic, but in the fully elongated shoot the phenomenon was readily reversed to one of normal appearance by the addition of agar. If left unchecked the vitrified shoot ceased growth and died some weeks later.

The re-introduction of high proportions of agar immediately stopped elongation and after 4 to 5 months shoots again deteriorated.

Attempts to prevent vitrification by increasing sucrose levels and Gelrite concentration alone were unsuccessful. A blend of agar and Gelrite provided the only satisfactory result. A range of gels were prepared from 100% down to 2%, from our standard concentrations if used alone, of 2gms/l Gelrite and 8gms/l DB agar. For example, a ratio of 50:50 comprised 1gms/l Gelrite and 4gms/l DB agar. A pattern emerged as the agar concentration dropped, of decreasing death, increasing elongation, and increasing vitrification. (Table 1 and Figure 2). Shoots were graded on a 1 to 3 scale which included the incidence and degree of each factor studied.

Table 1. Effect of Gelrite/Agar Blends Without BAP on Dieback, Elongation and Vitrification.

Gelrite/Agar Ratio				
Gelrite @ 2gms/l	Difco Bacto Agar @ 8gms/l	Die back @ 5 months	Elongation	Vitrification
0	100	+++	(+)	–
50	50	++	(+)	–
75	25	++	(+)	–
90	10	–	+	–
95	5	–	++	(+)
97	3	–	+++	+
98	2	–	+++	+++
100	0	–	+++	+++

KEY:

–	Nil	++	Moderate
(+)	Weak	+++	Marked
+	Slight		

We have been routinely using a 97:3 blend now for 12 months and find it gives us the greatest multiplication. Any vitrified shoots that occur are placed on the 90:10 blend briefly which corrects the phenomenon.

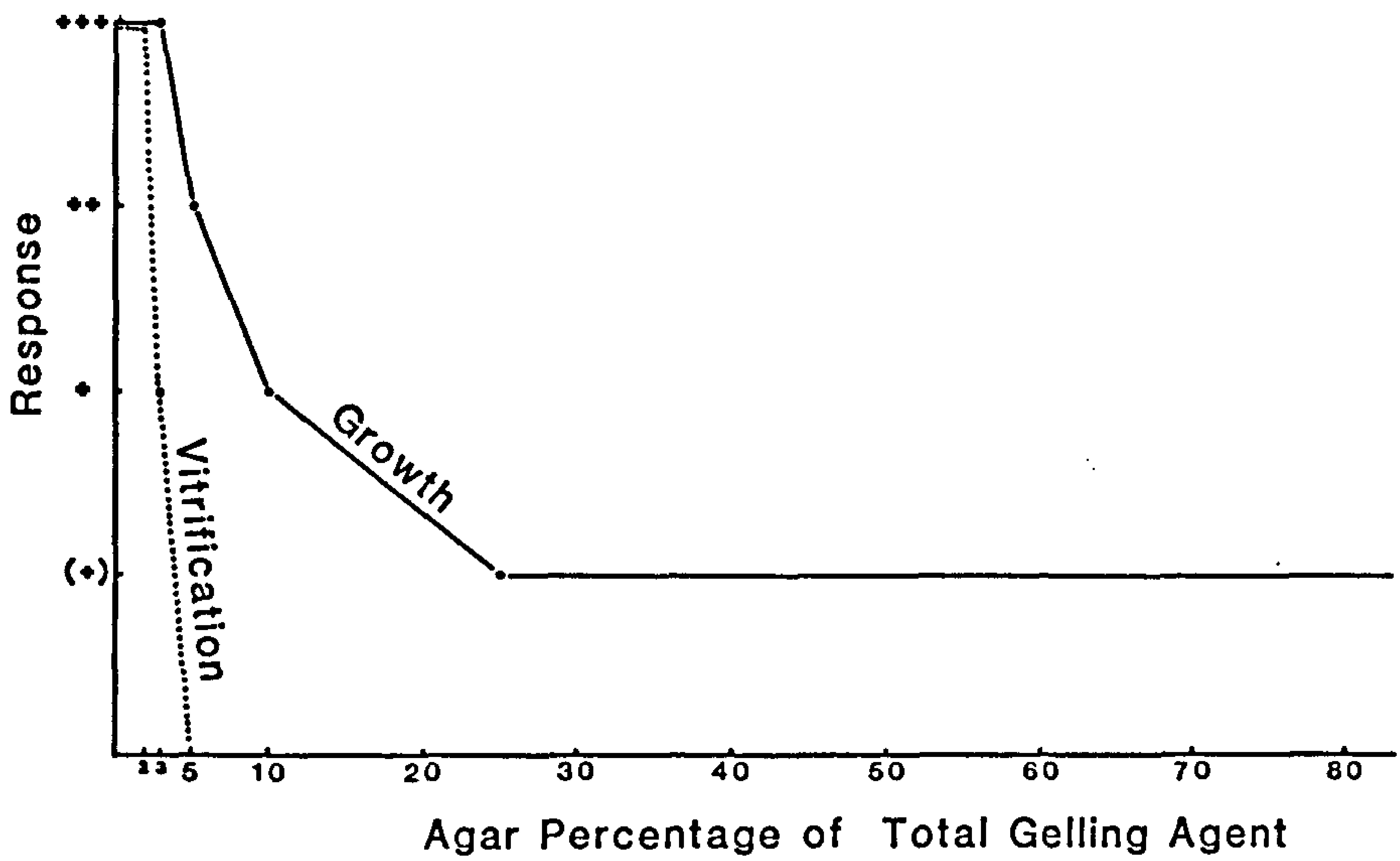

Figure 2. Shoot growth and vitrification as a function of agar ratio.

Table 2. Effects of Gelrite/Agar Blends With BAP on Dieback, Bud Form and Vitrification.

Gelrite/Agar Ratio					
Gelrite @ 2gms/l	DB Agar @ 8 gms/l	BAP mg/l	Die Back @ 4 Weeks	Bud Form	Vitrification
0	100	5	+++	Tight	–
50	50	5	++	Tight	–
50	50	3	++	Tight	–
75	25	5	++	Tight	(+)
90	10	5	–	Tight	+++
90	10	3	–	Tight	+++
90	10	0.5	–	Open	–
90	10	0.1	–	Open	–
90	10	0	–	Open (Low No.)	

KEY:

–	Nil	++	Moderate
(+)	Weak	+++	Marked
+	Slight		

SHOOT MULTIPLICATION WITH BAP

When cytokinin is added to the medium to stimulate axillary bud production, the tendency to vitrification becomes much higher, so a similar "titration" was carried out with cytokinin as an extra factor. (Table 2).

DISCUSSION AND FUTURE PROSPECTS

The incidence of vitrification in radiata pine tissue was controlled predominantly by the agar fraction of the gelling agents. Pasqualleto (5) describes similar results on the role of gelling agents for micropropagation of apple. In radiata pine 3 gms/l Gelrite alone resulted in vitrified shoots and the loss of growth, and because of this observation and the good growth on charcoal medium gelled totally with agar, the "anti-vitrifying" effects of agar appeared to be not only to do with matrix water potential, but a separately active agent present. The growth inhibition may be a combination of matrix potential and phytotoxic ingredients.

To elaborate this we tried several tests:

1. We pre-weighed 8 grams of DB agar and "washed" it in distilled water; after discarding the supernatant we then prepared media with the agar as usual. Vitrification was marked in shoot cultures. This is compatible with Boxus findings where the supernatant of hydrolysed agar prevented vitrification even in liquid medium (6).

2. Agarose type V was substituted for agar with the same gross vitrification resulting as washed agar. The gel strength here was comparable using 3 gms/l Agarose.

3. Davis Bacto grade agar gave identical end point results as Difco Bacto with a poorer shoot form resulting (with short spiralling needles at the crown). Charcoal corrected this malady.

4. Coast Biologicals (batch 950) agar gave a vitrification/elongation end point at a ratio of 75 Gelrite 25 agar with an open long-needled yellowish crown. This agar gave a better result as good growth was maintained without vitrification for 6 months.

The significance of gelling agents for radiata pine in a production laboratory has been shown. Further studies are required to elaborate the nature of these active fractions found in agar for plant species which are particularly sensitive to vitrification and toxicity.

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STERILIZATION OF NERINES USING THE TWIN SCALING TECHNIQUE

MICHAEL MACDONALD

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INTRODUCTION

Nerine, a genus belonging to the Amaryllidaceae family, is becoming an important ornamental bulbous plant in New Zealand. Already there have been large plantings of *Nerine* in New Zealand. *Nerine* species have a high potential as export cut flowers. However the natural multiplication rate of *Nerines* is fairly low. Although seed propagation can increase plantlet production by 1,000-fold, such a method does not maintain hybrid traits important for commercial crop production (5).

Large bulbs may only produce only a few daughter bulbs each year. To raise this multiplication rate growers have used a method known as "twin-scaling". This technique involves dividing the bulb into small portions, each consisting of a section of the basal plate. Grootaarts, et al. (2), showed that *Nerine bowdenii* bulblet regeneration always occurred at places where scales contained basal-plate tissue. This technique can be used *in vitro*, for most bulbous species including *Nerine* and *Narcissus* (1). Pierik and Ippel (4) developed the first *in vitro* twin-scaling technique for *Nerine bowdenii* and *Nerine sarniensis*. Bulblet regeneration from twin-scales *in vitro* is dependent on the size and age of the explant material as well as the position in relation to inner and outer regions of the bulb. Twin-scales taken from the outer region of *Nerine* bulbs, seem to regenerate bulblets better than those from the inner bulb (2).

Tissue culture techniques have been used commercially for *Nerine*. Various explant sources such as flower stems, twin-scales,

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Tissue culture techniques have been used commercially for *Nerine*. Various explant sources such as flower stems, twin-scales, and axillary shoots have been used (1). At the Department of Scientific and Industrial Research (DSIR), Palmerston North, New Zealand some *Nerine sarniensis* hybrids have been successfully micropropagated using flower stems (Balasingam, pers comm). Micropropagation of *Nerine* using twin-scale explants to form bulblets has not been attempted at DSIR. More recently, several commercial laboratories including Multiflora in Auckland, New Zealand, and Twyfords in England, have been successful using micro-twin-scaling *in vitro*. However, contamination by micro-organisms, especially fungi, is a problem in commercial laboratories. Contamination rates of up to 70% can occur. (Beynon, pers. comm.).

The objective of these experiments was to reduce the rate of contamination of *Nerine* twin scales by effective sterilization procedures and the use of systemic fungicides.

Three strategies were investigated:

1. Standard treatment of whole bulb with hypochlorite.
2. Treatment of bulbs with systemic fungicides and hypochlorite treatment.
3. Treatment of bulbs with fungicide and hypochlorite followed by dissection of twin-scales and resterilization with fungicide and hypochlorite.

MATERIALS AND METHODS

Plant material. Flowering size bulbs of *Nerine sarniensis* hybrids were collected from plants cultured under glass. Bulbs were collected from May 1987 to June 1987.

Experiment 1.

Step 1. The upper third of the bulb was removed together with the lower brownish part of the basal plate and roots. All soil was removed by washing. Bulbs were then left in a beaker of running tap water for 30 min. This procedure was used to reduce the possibility of contamination. Any visible necrotic tissue was also removed (Figure 1).

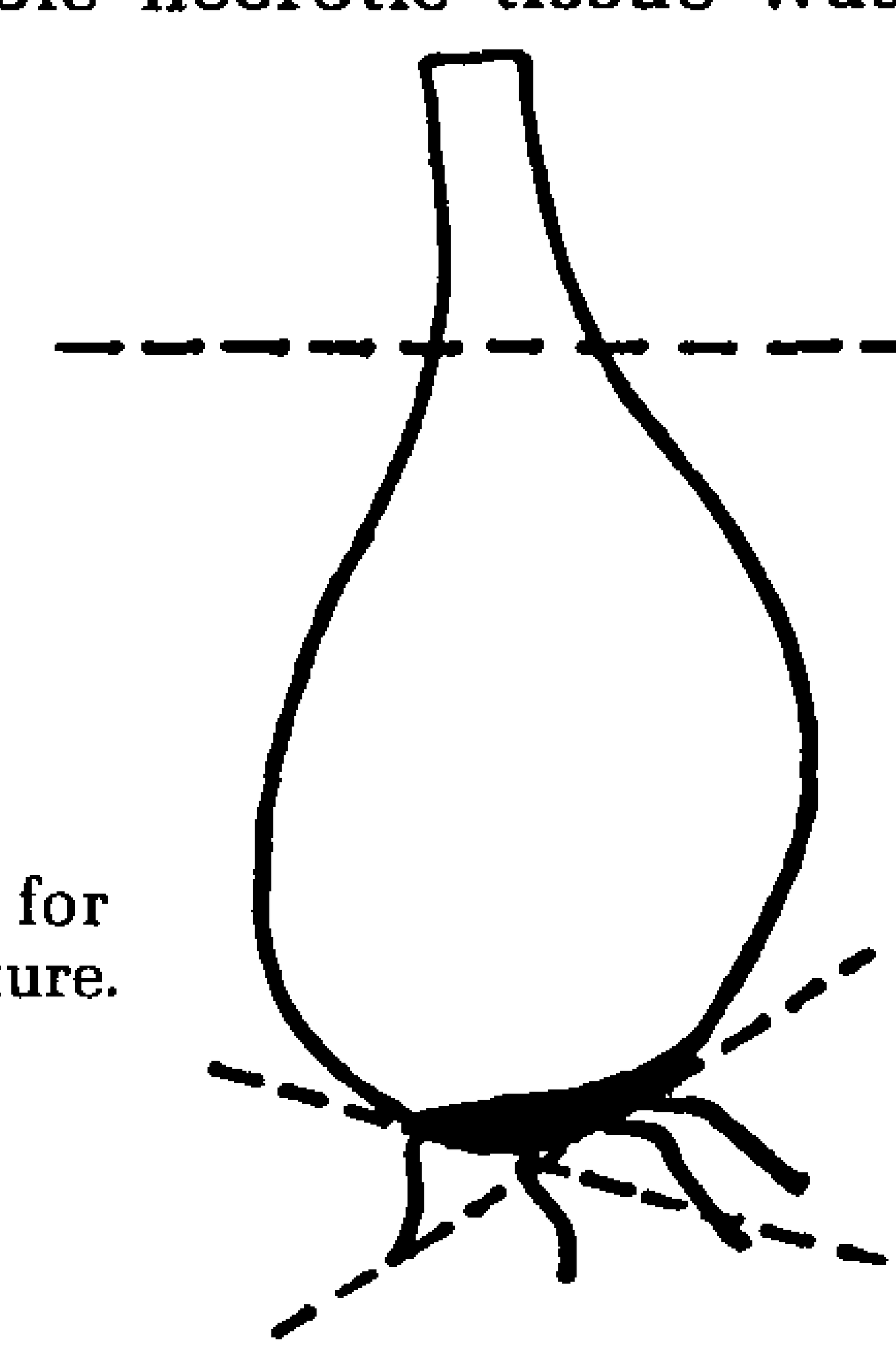

Figure 1. Clean-up procedure for *Nerine* bulbs before culture.

Step 2. Bulbs were surface sterilized in a 20% bleach solution (1% available chlorine) in 250 ml sterile jars and then placed on a shaker for 25 minutes. The bulbs were then rinsed three times in sterile water.

Step 3. Bulbs were then cut into segments for culture as shown in Figure 2.

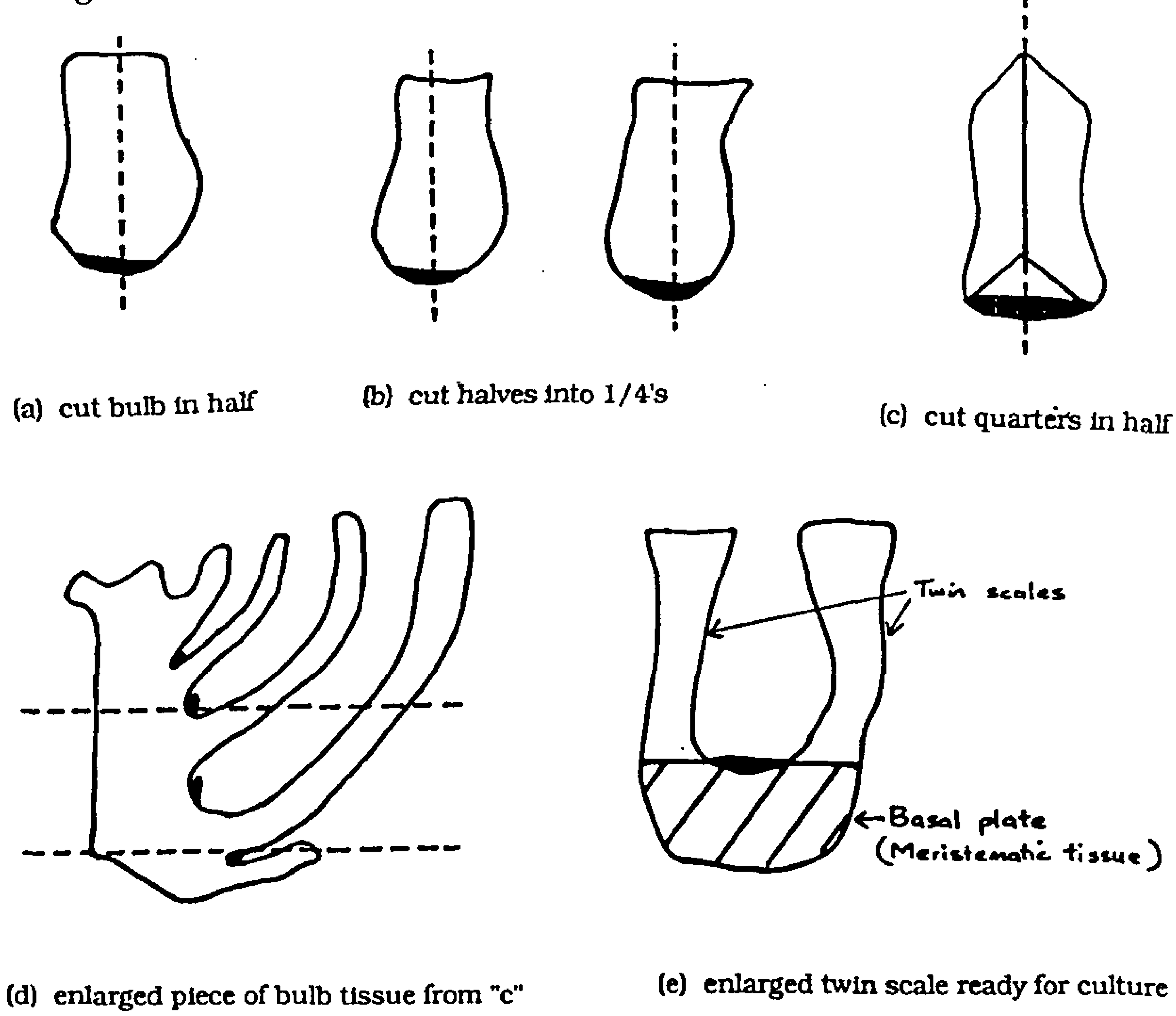

Figure 2. Method used for excising twin-scales from *Nerine* bulb tissue (a–e).

When excising bulb twin-scales, care was taken not to damage the basal plate tissue (scales were 1 to 1.5 cm long × 0.5 cm in diameter).

Step 4. Explants were placed directly into 15cm by 2cm Pyrex tubes containing 10 mls of Murashige and Skoog (MS) medium (3) with no cytokinin or auxin. Difco-Bacto agar was used at 0.7%. The tube was sealed and kept at a constant temperature of 25°C.

Experiment 2.

The same procedure was followed as for Experiment 1, using surface sterilization of the bulb in 20% bleach for 25 min. An additional treatment of 0.2% Benlate fungicide solution soak of the bulbs in 250 ml jars for 30 min. on a shaker was given followed by rinsing three times in sterile water. Bulbs were then excised into small 1 to 1.5 cm scale segments as described in Experiment 1 Step 3 a–e. Explants were then cultured onto petri dishes containing 10 mls of MS media.

Experiment 3.

Bulbs were surface-sterilized with 20% bleach for 25 min. on a shaker, then rinsed three times with sterile water. Bulbs were further treated with a 0.2% solution of Benlate on a shaker for 30 min. and rinsed three times with sterile water. Twin-scale explants were dissected out and resterilized in 0.2% Benlate for 30 min., rinsed three times with sterile water and then given 20% bleach for 25 min. followed by three rinses of sterile water.

Experiment 4.

Bulbs were surface-sterilized with 20% bleach for 25 min., rinsed three times in sterile water, and then given 0.2% Benlate for 30 min. followed by three sterile water rinses. Twin scales, 1 to 1.5 cm, were excised from the bulbs and treated with 0.2% Benlate solution for 30 min. then 10% bleach and rinsed three times with sterile water. Jars were placed on a shaker through all treatments. Explants were cultured on petri dishes containing 10 mls of MS medium.

Experiment 5.

Bulbs were surface sterilized with 0.2% Benlate for 30 min., rinsed three times in sterile water and then given 20% bleach for 25 min. Twin-scale explants were then excised and resterilized with 0.2% Benlate for 30 min., rinsed three times in sterile water, and then given 20% bleach for 25 min. followed by three rinses in sterile water.

All experiments were kept at a constant temperature of 25°C.

RESULTS

Figure 3 gives a summary of the results. The following results were observed and recorded.

Experiment 1. After two weeks in culture, 97% contamination was recorded. The contamination was 80% fungal and 70% bacterial infection.

Experiment 2. After one week 90% contamination was recorded.

Experiment 3. After one week 15% contamination was recorded.

Experiment 4. After one week 10% contamination was recorded.

Experiment 5. After one week the contamination was 6%.

For identification of contaminated tissue, pure cultures were made of the fungi and bacteria, and identified by Massey University Pathology Department. The fungus *Cladosporium* spp., a common contaminant, was found not to be a pathogen in this case. Bacteria, also was not found to be a plant pathogen.

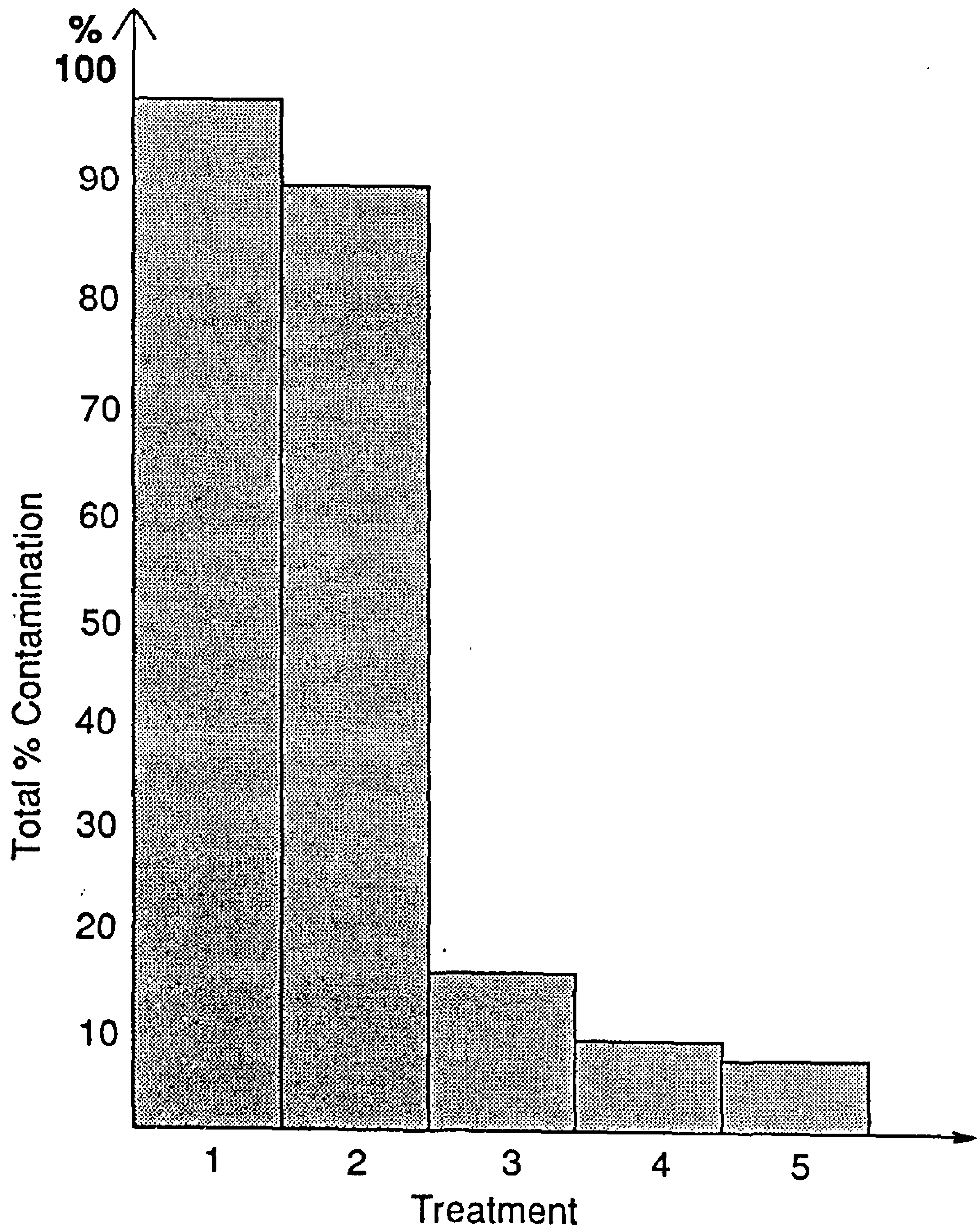

Figure 3. Percentages of contamination for Experiments 1 to 5.

DISCUSSION/CONCLUSIONS

Because bulb tissue is directly in contact with the medium or soil, the risk of contamination from soil pathogenic fungi and bacteria is greatly increased. Bulb tissue is difficult to free from contamination for tissue culture purposes. Up to 60% of double scale segments and 40% of basal plate tissue from hyacinth can be contaminated (1). This rate is high compared with the adventitious plantlet regeneration from floral stem explants of *Nerine bowdenii* W. Watts. The contamination rate for this method was much lower at 5 to 10% (5).

The first method for twin-scaling of *Nerine bowdenii in vitro* (4), used a sterilizing technique by immersion of quarters in 70% ethanol for a few seconds. The quarters were then rinsed in 20% bleach for 25 min., then three times in sterilized water for 25 min. When this procedure was followed carefully an infection rate of 10% was found (4). In the experiment reported here ethanol treatment was not used because of the risk of damaging the delicate twin-scales. Also, in the preliminary experiments 1 and 2, fungal contamination was the main pathogen, thus the reason for introduction of a fungicide treatment.

From the experiments conducted here it is evident that surface sterilization of the excised twin-scales is necessary to reduce the contamination rate of *Nerine sarniensis* hybrid bulb tissue. Even with the treatment of bulbs with 20% bleach *and* 0.2% Benlate, a 90% contamination rate was still recorded. Compare this with the next treatment in experiments 3 to 5, with treatment of bulbs *and* resterilized excised twin-scales where only 6 to 15% contamination was found.

This project, however, has only researched the sterilization of twin-scales of *Nerine sarniensis* hybrids, and further research is needed to induce bulblet information on the twin scales before this method can be safely used on other members of the Amaryllidaceae.

Acknowledgements. I wish to thank my supervisor throughout this project, Mr. G. Balasingam, Plant Physiology Division, (P.P.D.) DSIR, Palmerston North, for his guidance and for generously supplying the *Nerine* hybrids. I would also like to thank Dr. D. Cohen, P.P.D. (DSIR), Palmerston North, for valuable discussions and use of the laboratory facilities, Mr. Bruce Christie and Ms. Wilmein Braschcamp for their support throughout this project.

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AFFORESTATION OF SALT-AFFECTED SOILS—AN INTERNATIONAL PROBLEM

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INTRODUCTION

Salt-affected soils cover 10 per cent of the globe and a further 20 per cent are of marginal use (10). Furthermore, the world demand for timber is reducing the amount of forest cover globally by 0.6% (11,303,000 ha per annum) (13) or, in equivalent terms, an amount of afforested land equivalent to the size of Kew Gardens (120 ha) ceases to exist every six minutes. These are frightening statistics by any standards and, perhaps because we in Western Europe are not directly concerned, we view them with some complacency.

Recently, I was fortunate enough to view many of these problems first hand when I attended two international Symposia in India, one on this topic and one on "Agroforestry for Rural Needs". This paper largely reports the ways that were discussed of combating problems of growing trees in salt-affected soils, and particularly the immediate problems raised by the high population pressures and arid conditions in India.

ESSENTIAL INFORMATION REQUIRED TO BE ABLE TO OVERCOME AFFORESTATION PROBLEMS

There are a number of methods used in attempting to minimise such problems. If they receive the attention they deserve we might be able to go some way towards mitigating the problem before it is too late. The major methods that can be used are:

1. A much more concerted attempt to persuade governments of tropical countries against "clear felling" policies.
2. Continued research and development into soil characteristics and methods of amelioration.
3. Improved irrigation systems in arid zones and an understanding of the hydrology of those regions.
4. Continued selection and evaluation of salt-resistant clones (particularly of timber species).
5. Rigorous selection of indigenous species for high yielding characteristics in terms of fuel, fodder, and timber.
6. Continued development work and trialling of a range of planting methods for different species/site characteristics.

Characteristics of salt-affected soils. The types of salt-affected soils that cover the earth's surface are divided into five main groups (10). These are as follows:

Saline soils. These develop mainly under the influence of electrolytes of sodium soils with nearly neutral reaction. These are predominantly NaCl and Na_2SO_4.

Alkali soils. These soils develop under the influence of electrolytes capable of alkali hydrolysis. Mainly Na_2CO_3 and $NaHCO_3$. Soils with a high ESP (exchangeable sodium percentage) are termed "sodic soils".

Gypsiferous soils. These are salt-affected soils that develop mainly owing to the presence of $CaSO_4$ and occasionally $CaCl_2$.

Magnesium soils. Salt-affected soils which develop under the influence of magnesium salts.

Acid sulphate soils. Soils in which the salt content is composed mainly of Al_2SO_4, Al_2SO_3, or Fe_2SO_4, Fe_2SO_3.

The chemical and physical properties, effects on production and methods for reclamation are detailed in Table 1, and the details of Indian soils of this type have been described (1) and are listed in Table 2. The electrochemical criteria for salinity, sodicity and alkalinity are detailed in Table 3.

Table 1. Grouping of Salt Affected Soils [After Szabolcs (10)].

Type of salt affected soil	Environment	Electrolyte/s/ causing salinity and/or alkalinity	Main adverse effect on production	Method for reclamation
1) Saline soils	Arid and Semi-arid	Sodium chloride and sulphate (in extreme cases—nitrate)	High osmotic pressure of soil solution (toxic effect)	Removal of excess salt (leaching)
2) Alkali soils	Semi-arid Semi-humid, humid	Sodium ions capable of alkaline hydrolysis	Alkali pH Effect on water physical soil properties	Lowering or neutralizing the high pH by chemical amendments
3) Gypsiferous soils	Semi-arid Arid	Calcium ions (mainly $CaSO_4$)	Acidic pH, Toxic effect	Alkaline amendments
4) Magnesium soils	Semi-arid Semi-humid	Magnesium ions	Toxic effect high osmotic pressure	Chemical amendments (leaching)
5) Acid sulphate soils	Sea shores, lagoons, with heavy, sulphate containing sediments	Ferric and aluminum ions (mainly sulphates)	Strongly acidic pH, toxic effect	Liming

Afforestation of soils without irrigation. This is possible where: a) the average precipitation is sufficient for tree growth, or b) the level of soil salinity/alkalinity is below the toxic threshold value for silviculture.

This method of afforestation is possible in countries such as the USSR, Spain, Romania, Yugoslavia, and Hungary. To be effective it has to be combined with well organised and defined agricultural practices, specific to the region. Afforestation without irrigation is possible in more arid conditions such as those experienced in Australia (12), but here careful selection of certain species of resistant trees is crucial (11). Examples of two such genera are: *Eucalyptus* and *Acacia*.

Table 2. *Geoclimatic Distribution and Characteristics of Salt-Affected Soils in India* [after Bhargava (1).]

Soil class	Main characteristics	Mean annual rainfall (mm)	Distribution
1. Alkali soils of Indo-Gangetic alluvial plain.	High pH, EC, ESP and preponderance of sodium bicarbonate and carbonate.	600 to 1000	Parts of Punjab, Haryana, Uttar Pradesh, Bihar and Rajasthan states.
2. Inland saline soils of arid and semi arid regions.	Neutral to alkaline pH, high EC and preponderance of chlorides and sulphates.	Less than 500	Parts of Haryana, Punjab and Rajasthan states.
3. Inland saline soils of sub humid region.	Neutral to alkaline pH, high EC, preponderance of chlorides and sulphates.	1000 to 1400	North Bihar
4. Inland salt affected deep black soils (vertisols).	Neutral to highly alkaline pH, high EC, preponderance of chlorides and sulphates with or without bicarbonates. Montmorillonitic minerology.	700 to 1000	Parts of Madhya Pradesh, Maharashtra, Rajasthan, Andhra Pradesh, Gujarat and Karnataka states.
5. Medium to deep black soils of the deltaic and coastal semi-arid regions.	Neutral pH, high EC, preponderance of chlorides and sulphates. Montmorillonitic minerology.	700 to 900	Saurashtra coast in Cujarat and deltas of Godavari and Krishna rivers in Andhra Pradesh.

Soil class	Main characteristics	Mean annual rainfall (mm)	Distribution
6. Saline micaceous deltaic alluvium of humid regions.	Neutral to slightly acid pH, high EC, preponderance of chlorides.	1400 to 1600	Sundarban delta in West Bengal and parts of Mahanadi delta in Orissa state.
7. Saline humic and acid sulphate soils of humid tropical region.	Acid pH, high EC, presence of humic (organic horizon) preponderance of chlorides and sulphates.	2000 to 3000	Malabar coast in Kerala state.
8. Saline marsh of the Rann of Kutch.	Neutral to slightly alkaline pH, high EC, preponderance of chlorides and sulphates.	Less than 300	Rann of Kutch in Gujarat state.

Table 3. Criteria For Salinity, Sodicity and Alkalinity [After West (12), adapted from Northcote and Skene, 1972, SCSC 1982].

	Non-saline	no chloride salinity in either the surface soil or subsoil as defined for categories below.
Salinity	surface salinity	soils having in their A horizons, (or in the surface 20 cm if, either the A and B horizons are undifferentiated, or, the A horizon is <10 cm thick) electrical conductivity (EC^{+}_{e}) values more than 400 mS m^{-1} (more than about 0.1% sodium chloride), in loams and coarser soils, and more than 800 mS m^{-1} (0.2%) in clay loams and clays.
	subsoil salinity	soils lacking surface salinity, but having EC_e values more than 1200 mS m^{-1} (0.3% sodium chloride) in the B horizon, or below 20 cm if the A and B horizons are undifferentiated.
Sodicity	non-sodic	*ESP <6
	sodic	*ESP 6–14
	strongly sodic	*ESP >15
Alkalinity	acidic or slightly alkaline	pH <8.0
	alkaline	pH 8.0–9.5
	stronglyalkaline	pH >9.5

* Exchangeable sodium percentage
\+ Electrical conductivity of saturation extract at 25°C

Afforestation of salt-affected soils with irrigation. In arid and semi-arid regions of the world, irrigation is a precondition of successful tree establishment. This may or may not be coupled with a need for drainage. Four main establishment methods are generally recognized:

1. The old traditional method of irrigating trees via ceramic jars. Practised in North Africa and the Middle East.

2. The use of large-scale irrigation canals as a major means of water transport. Used in semi-arid areas of India, China, USSR, USA.

3. The afforestation of saline soils by the application of gypsum and other amendments, coupled with artificial drainage.

4. More complex methods for the application of up-to-date hydrological techniques, often in areas of importance for agriculture, silviculture, or recreation.

SELECTION OF SUITABLE SPECIES FOR SALINE OR SODIC SOILS

This is an area where much basic groundwork has been undertaken, based largely, in the first instance, on observational experiments with local flora and associated genera, and then with the selection (often clonally) of non-indigenous species, of which *Eucalyptus* is a good example for Indian conditions. There is a problem here with the assessment of the value of information gained from juvenile material, often grown in restricted root

Table 4. Trees and Shrubs Grown in the Semi-arid Conditions of Australia [Adapted from West (12)].

FOREST TREES		
1)	Trees suitable for saline soils	*E. platypus*
	Eucalyptus astringens	*E. polyanthemos**
	E. brockwayi	*E. sargentii*
	E. camaldulensis	*E. wandoo**
	E. cladocalyx	*E. woolsianna**
	*E. largiflorens**	*Leptospermum lanigerum*
	*E. leucoxylon**	*Melaleuca lanceolata*
	*E. mannifera**	
	E. occidentalis	
2)	Softwoods and other species	*P. radiata*
	Pinus caribaea	*Populus* spp.
	P. elliottii	
	P. pinaster	
TREES USED FOR FARM FORESTRY AND FODDER		
Acacea aneura and related spp. (wattles)		
Brachychiton populeum (kurrajong)		
Ceratonia siliqua (carob)		
Cytisus prolifer (tagasaste)		
Gleditsia triancanthos (honey locust)		
Leucaena leucocephala (leucaena)		
Salix spp. (willows)		
SHRUBS		
A wide range of species of halophyte shrubs		

* Indicates species particularly suitable for drawing on saline groundwater to reduce discharges into watercourses

environments such as those found within containers. This is a difficulty often seen by experimental foresters but is, perhaps, particularly acute in this instance.

Examples of salt tolerant indigenous trees and shrubs trialled in northern India and of species selected in Australia (the world's driest continent) for tolerance to adverse conditions are given in Tables 4,5,6.

Table 5. Tolerance of Eucalyptus Provenances to Saline Conditions (after Thomson (11)).

Species	Provenance	NaCl level (M) causing mortality Mean	S.E.	Homogeneous subsets[1]
E. camaldulensis	DeGrey R.	0.64	±0.011	a
E. camaldulensis	Silverton	0.61	±0.013	ab
E. camaldulensis	Wiluna	0.61	±0.012	ab
E. tereticornis	Loch Sport	0.59	±0.013	bc
E. camaldulensis	Pentecost R.	0.59	±0.011	bc
E. camaldulensis	Emu Creek	0.57	±0.012	cd
E. rudis	Wagin	0.54	±0.012	de
E. camaldulensis	Quilpie	0.53	±0.013	def
E. camaldulensis	Kangaroo Is.	0.52	±0.012	efg
E. tereticornis	Laura	0.51	±0.015	efg
E. camaldulensis	Lake Albacutya	0.51	±0.012	efg
E. tereticornis	"Strathfieldsaye"	0.51	±0.013	efg
E. camaldulensis	Whiteheads Ck.	0.51	±0.013	efg
E. camaldulensis	Minlaton	0.50	±0.014	efgh
E. rudis	Sth. Yunderup	0.50	±0.013	efgh
E. camaldulensis	Douglas	0.50	±0.013	efgh
E. tereticornis	Kenilworth	0.49	±0.011	fgh
E. camaldulensis	Katherine	0.49	±0.013	gh
E. camaldulensis	Moree	0.47	±0.012	hi
E. tereticornis	Raymond Terrace	0.44	±0.011	i

[1] Provenances which do not share a common letter have means which are significantly different at the 5% level

Table 6. Local Trees of Economic Importance in Haryana, India.

Acacia nilotica	*Eucalyptus* spp.
Azadirachta indica	*Ficus religiosa*
Butea monosperma	*Prosopis cineraria*
Dalbergia sissoo	*Salvadora oleoides*
Species key-trialled by CSSRI Experimental Stations	
Acacia auriculiformis	*Melia azedarach*
Acacia nilotica	*Parkinsonia aculeata*
Acacia torta	*Pongamia pinnata*
Albizia lebbeck	*Prosopis juliflora*
Callistemon lanceolatus	*Salix babylonica*
Casuarina equisetifolia	*Syzygium cumini*
Casuarina glauca	*Tamarindus indica*
Eucalyptus camaldulensis	*Tamarix gallica*
Eucalyptus, hybrid	*Terminalia arjuna*
Leucaena leucocephala	

TRANSPLANTING TECHNIQUES

There are a number of transplanting techniques used on difficult soils of this type and the preference for the method chosen varies with the type of soil problem to be overcome and the species, or an interaction of the two. The problem is complex in many instances, as there are competing factors. One of the main problems to consider is that a system of planting involving irrigation may over the years raise the water table of a saline soil, and thus requires very careful hydrological management. The consequence of neglect here is total crop loss caused by toxic levels of salts in the soil water causing root death. Conversely, planting systems with minimal irrigation and maximum aeration, such as ridge systems, may give rise to situations that are extremely prone to water loss although well aerated.

There are five main transplanting methods, these being: pit, channel, auger hole, mound, and ridge.

Pit. This is a system similar to many European planting systems where initially a pit is dug and then backfilled with amendments. It is generally practised on level land.

Channel. The channel system is just as it suggests. Young trees are planted into a channel into which irrigation water may be diverted. The problems here are the possibility of excess salt build-up near the surface and waterlogging during heavy rains, unless well managed.

Auger hole. A simplified version of the pit system. Again it is used for plantings on the flat and is similar to some European systems.

Mound. Trees are planted above the soil level with the roots in individual mounds of earth. This system provides good aeration but is obviously restrictive as far as water availability is concerned. Growth rates are slower in this system but percentage establishments generally higher.

Ridge. A continuous ridge within which the trees are planted. The physical and biological limitations are similar to those described for the mound system.

Examples of salt levels seen within three of these systems in Sampla, Haryana, northern India, are shown in Figure 1.

DISCUSSION

There are highly complex biological and physical constraints on the growth of trees in the normally arid salt-affected soils. Such situations apply to soils formed in the USSR, Australia, the central European land mass, USA, and Africa, as well as India. Often the constraints are not only biophysical but social and economic too.

In countries such as India with deeply rooted agricultural traditions coupled with the problems of inhospitable soils and the ever-

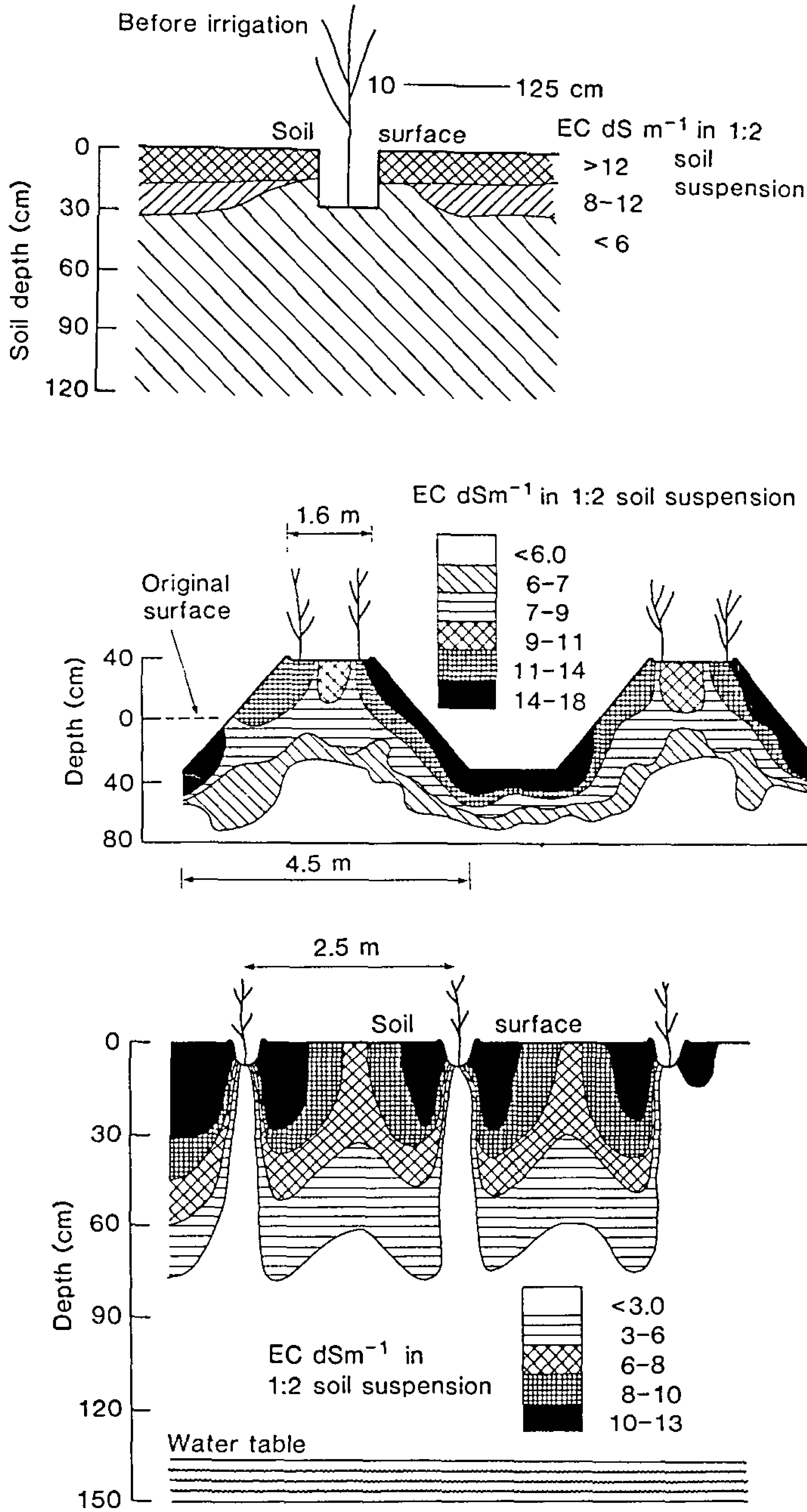

Figure 1. Examples of salt levels seen within three transplanting systems in northern India.

present threat of drought, deviations in agricultural practice involve social change. Here the extension worker is of paramount importance, as often only he can bring the real benefits of new agricultural practices to the notice of the rural population. Even when this is done a protocol must be observed when approaching village communities and the responses from neighbouring areas may differ markedly (6). A striking example seen in Haryana was the increase in yield by approximately 80-fold that was observed following the cultural, fertiliser and soil amendment regimes proposed by The Central Soil Salinity Research Institute, Karnal. In particular an integrated approach to timber (and therefore fuel) production and windbreak use was improving the agricultural potential of the land (7).

The concentration of effort must be made on three fronts.

Firstly, the basic science input that has been done must be maintained and, in particular, modern techniques for selecting new germplasm for salt resistance, employing such methods as intraspecific hybridization, and *in vitro* methods (including tissue culture techniques and recombinant DNA technology), must be developed along with traditional screening of large germplasm collections, particularly those from salt-affected areas (9,11).

Secondly, large scale data collection and assessment of potential land use must continue. For example in India alone, Grewal and Abrol (4) point out that 40 million hectares of land potentially cultivatable are lying barren due to severe soil constraints. Of these, 2.5 million hectares were of alkali soils (2), this figure increasing to 7 million hectares when saline soils are also included (5). Furthermore, Bhumbla (3) pointed out that the Indian land mass occupies 329 million hectares of which between 53 and 175 million ha are wasteland. He drew attention to the increasing population pressure with a projected population for that sub-continent being 970 million by the year 2000 AD. The decreasing ratio of land: population poses a serious problem and it is estimated that, in volume terms, 6000 million tonnes of soil are lost per annum from a possible agricultural use to direct human use. In conjunction with such land use and social studies, the important work of soil mapping must continue as must the large scale study of potential water resources (8).

The same problem is also present in highly developed countries and land masses of which Australia is an example of a country with arid zones but a low population pressure. West (12) estimated that this continent has 32 million ha of saline dryland of which 28 million are naturally salinised and four million have become salinised as a consequence of European settlement. Furthermore, secondary salinisation of surface waters is a serious problem, particularly in southern Australia with high costs to industrial, agricultural and domestic users.

This is a major problem for arid zones, in a world with fast diminishing natural resources. Attempts to integrate the approaches described above are **vital**—not academic, if we are to attempt to preserve some global ecological balance.

Acknowledgements. I thank Dr. I. P. Abrol for inviting me to India, and Dr. R. S. Rana for much help and advice whilst in that country. I should also like to thank the British Council and the Thomas Phillips Price Trust for financial assistance.

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HARLOW CAR GARDENS AND THE TRADE

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INTRODUCTION

Harlow Car Gardens is the headquarters of the Northern Horticultural Society (NHS), an organization established just after World War Two to serve home gardeners in the north of England—its traditional area of activity having been "twixt Trent and Tweed". Today the NHS has a wider remit and its gardens fill a more extensive role than could have ever been envisaged by the founders.

The original concept of a trial gardens for the north of England remains, but Harlow Car is also of international stature and maintains an important living collection of horticultural and botanical subjects. A member of the International Association of Botanic Gardens and a centre for the teaching and examinations of the City and Guilds of London Institute and The Royal Horticultural Society, Harlow Car is a remarkable hybrid without parallel in the United Kingdom.

Situated some 150 metres above the sea level on the edge of the Yorkshire Dales and on a heavy acid clay soil, it presents gardeners and nurserymen with a realistic picture of what can be achieved in a harsh northerly climate on an uncompromising soil. Consisting of over 24 ha of landscaped gardens, Harlow Car not only conducts horticultural trials, but aims to embrace a wide diversity of horticultural activities. An arboretum, woodland, rock and heather gardens, together with bulb and rose gardens, display a broad range of plant material for study and enjoyment. The recent addition of a greenhouse teaching facility has further advanced the opportunities available for both public and vocational education. Together with the study centre, which comprises a classroom, horticultural library, and accommodation for botanical collections, Harlow Car offers anyone interested in horticulture or botany a unique opportunity to improve their knowledge.

Funding. For the maintenance and development of the gardens this comes primarily from the membership of the NHS (which now has reciprocal terms with The Royal Horticultural Society), gate receipts, and grant aid and support from bodies like the Countryside Commission and Manpower Services Commission. An educational charity, the NHS is independent and receives no direct government aid, so the support of the gardening public and the horticultural trade are vital for its continued success.

Relationship with the trade. In years gone by, it was a popular notion within the trade that Harlow Car was somewhat sophisti-

[1] Curator

cated, purist, and untouchable. On my arrival seven years ago that was certainly the impression which colleagues in the trade gave to me and I can understand how it arose, for there were people within the Society who considered the trade to be vulgar and that Harlow Car should not readily associate with it.

I hope that over the past few years much of the misconception about what we are and who we are has been dispelled. I must here thank the local field officer of the Horticultural Trade Association, Mr. Jim Parnham and the Regional Horticultural Advisor of the Agricultural Training Board, Mr. Guy Lloyd, for having assisted me greatly in both using Harlow Car and introducing it to the trade in the north of England.

Plant collections. With current happy relationships I can see the development of links between Harlow Car and the trade continuing not only in present areas of activity, but diversifying into others too. Harlow Car is an important living plant resource. It is not just a pleasant garden where the wares of the nursery stock industry are displayed, but a reservoir of plant material just waiting to get out into the trade.

We have no intention of becoming a stock bed for the nursery industry, but we are a source of propagating material when a grower wishes to introduce a new line. This new line may be truly new to the trade, such as a collection from a Chinese or Chilean expedition, or it may be an old cultivar that is returning to popularity.

The living plant collection at Harlow Car is available to the trade, and while all our holdings have yet to be recorded in detail, the woody plant collection is in order and it is hoped that a catalogue of our woody plant resources can be made available to interested parties in the near future. An idea of the range of seed-bearing plants growing at Harlow Car can be obtained from our annual Index Seminum (seed list). Primarily prepared for distribution to our members and to botanical and horticultural institutions world-wide, we are always happy to send members of the trade a copy and to deal as sympathetically with their requests as possible. Again, it is intended that the seed resource be used as a means to obtain stock, rather than to be a continual annual source of the same material.

The living plant collection has another function too, that of a permanent advertisement for the plant kingdom. It is true that we grow many plants which are unlikely to ever be sensible propositions for the nursery stock industry, but we do maintain most of the important species and cultivars grown by the trade and suitable for northern gardens. The trade can assist us greatly in the promotion of its plants and products by ensuring that we know about them and, whenever possible, sending material to us for display. While we cannot actively promote companies in a commercial sense, cultivars of new plants, even when licensed for production by a single grower, can legitimately be displayed and their merits espoused.

Seed trials. In the seed trade this is often done in our trials of new cultivars or demonstrations of cultivars of a single genus. Evaluations are made for home gardeners in our quarterly journal, *The Northern Gardener,* and we seek to be positive, recommending good cultivars, but not damning the less successful. The public can make their own visual analysis of our trials and judge for themselves the usefulness of each.

A more detailed analysis of our trials is often available, depending upon the criteria established at the outset and the body for whom we are conducting trials. With the increase in cooperation with the Royal Horticultural Society (RHS) it is expected that many of our trials will be conducted in parallel with those at Wisley, the RHS gardens. Apart from trials and demonstrations conducted in the public part of the garden for the benefit of the home gardener, we undertake trials financed by companies and growers in a private area and produce detailed reports on plants that they are considering launching upon the home gardening market.

An important new clonal selection programme is currently under discussion with a major grower group and it is this kind of cooperation which we are anxious to see become part of our trials and research programme.

Training programmes. Alongside the practical work within the gardens we operate a training programme for young people. This is now a formalised scheme and grew out of our desire to use the plant collections for teaching, particularly of those who have a practical aptitude rather than an academic one.

An initial informal programme has now developed into what we consider to be one of the finest basic craft skills courses in the country. Not a course to replace anything offered by the horticultural colleges, but one which provides good basic skills for those who wish to later attend college, and more importantly a craft skills and plant knowledge oriented programme which provides the grounding for skilled craftsmen, workers who are in increasingly short supply in the nursery industry. Despite the fact that our training is not industry oriented, many of our trainees have found satisfactory employment in the trade.

It was a belief that this would be so, that led the Agricultural Training Board (ATB) to support our training programme and embrace it within the Horticultural Training Scheme—as far as I know the only training provided at a non-commercial establishment thus approved. This is very useful for the non-academic trainee who requires some kind of on-going structured training which he can take with him into the industry.

Trainees are primarily accepted through the Youth Training Scheme (YTS), operated by Harrogate Borough Council, although we do have a number outside this group who are usually a little older and funded independently. The latter generally spend a year with us, but those on the YTS programme have a full two years at the gardens.

Practical training in all aspects of horticultural practice is provided by circulating the trainees around the different departments of the gardens. Formal instruction consists of City and Guilds Phase 1—Principles of Horticulture, and City and Guilds Phase 2, Year 1, Amenity Horticulture—both being taught in-house. In addition, other formal instruction includes plant identification tests and the opportunity to study evening courses such as the RHS General Examination in Horticulture.

Evening classwork is not compulsory, trainees joining non-vocational students on such courses without charge if they are sufficiently motivated. While we do not direct our training towards the trade, we do feel that our trainees are suitable material for the trade to work with, foundation skills and basic plant knowledge having been established. Already this is being appreciated locally and approaches for suitable young workers have been made by a number of nurseries and several have entered and established themselves successfully in the industry.

Apart from our trainee programme we instruct and host short courses for the ATB. These are usually plant oriented, although a very successful course for retailers of garden chemicals has been instituted and the entire plant identification package used nationally was developed at Harlow Car. With the broadening remit of the ATB, it is likely that our links with the trade in this field of training will continue to develop. Professional seminars instituted by ourselves and also hosted on behalf of other organizations like the Institute of Horticulture regularly feature in our calendar. Events hosted by different sectors of the trade, although a recent innovation, are likely to be an area of expansion.

Harlow Car Gardens is an outward looking organisation which seeks to embrace all horticultural interests. From very tenuous and often uncomfortable links with the trade in years gone by, it has grown and developed so that now a happier liaison exists. A realization that both the Northern Horticultural Society and the horticultural trade had common interests which should be jointly exploited has developed into a burgeoning bud. It now needs steady feeding to ensure that it turns into a full blown blossom.

BASE HEATING FOR PROPAGATION: FLEXIHEAT

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INTRODUCTION

Flexiheat is the trade name for low voltage electrically heated mats, distributed by Foil Engineering, Ltd of London. They operate at a safe 24 volts, and generate 14 watts for each 300mm length of foil element. The elements consist of aluminum or nickel foil, laid out in an intricate winding pattern, similar to the original printed circuit boards which revolutionised the electronics industry. For horticultural use, the elements are mainly aluminum foil, and the electrical connections consist of cold copper tails soldered onto a pair of foil busbars, running down each side of the active heating element. The resultant mat is then encapsulated between two layers of polyester film, making it impervious to moisture or chemical fluids.

Each mat has a total width of 380mm, with a foil width of 350mm, including the two busbar strips. The active heating section of the element in the centre is 250mm wide, and designed to form a complete circuit module every 600mm. Table 1 shows how the wattage per square metre can be varied by overlapping the busbar strips, or the busbar strips can overlap the active heating area, but the active heating sections must never overlap each other, as this could cause overheating.

Table 1. Flexiheat mats heat output. (28 watts per 600mm complete circuit module at 24 volts; 14 watts every 300mm run.

		Equivalent Wattages	
120 watts/m^2	over	380mm	plastic width
129 watts/m^2	over	350mm	foil width
151 watts/m^2	over	300mm	overlap
181 watts/m^2	over	250mm	active sheathing width

MAIN ADVANTAGES

Low voltage safety. The mats operate at 24 volts, reduced from the main voltage of 240 volts, through a transformer.

Even heat distribution. The overall heat pattern achieves improved efficiency in propagation, without relying on a large bulk of sand to provide the heat transfer to the seed trays. However, if full benefit is to be obtained from the Off Peak "Economy 7" tariff, some form of thermal storage is recommended. As with any heat source, there is still the difficulty of obtaining an efficient heat

[1] Agricultural Development Engineer

transfer to the compost if polystyrene based trays are used, and these should be avoided if possible.

Simple installation. Mats can be rolled out onto an insulated bench, and just covered with capillary matting, or laid into an insulated sand bed.

Mobility. Flexiheat mats can be easily rolled up again for storage if required.

Sterilisation. Steam sterilisation is easy, as the foil is resistant to temperatures of up to 120°C. It will also withstand most known chemicals used in sterilisation.

Long life. Although the mats are waterproof and the encapsulated foil virtually indestructible the life span can be extended considerably if a sheet of heavy gauge polythene is laid over them, or they are enclosed in a polythene sleeve before covering with sand. This provides additional mechanical protection from any pieces of sharp grit, and more important, prevents the mats from becoming submerged in any liquid fertiliser or chemical fluids, which could cause corrosion of the electrical connections.

Where mats consisting of three or more complete element modules are used, any mechanical damage causing a break in the foil elements will result in the current finding an alternative route via adjacent arms. Thus any loss of heat will be restricted to one or as many arms of the pattern that may be damaged. This will be largely compensated for by a slight increase in heat output by the remaining arms.

INSTALLATION

Root zone warming is only one factor affecting plant growth, and the use of low voltage matting does not excuse the system from the basic rules. It is impossible to list here the environmental requirements of all plant species, but whatever type of heating system is chosen, it must be capable of maintaining a temperature range of between 12° and 25°C. Table 2 lists just a few typical environmental regimes.

Table 2. Typical glasshouse environmental temperature regimes.

	Air temperature, °C		
	Day	Night	Root zone °C
Bedding plants	5–12	5–12	15–25
Nursery Stock	5–10	5–10	16–22
Ornamentals	15–24	15–24	18–25
Chrysanthemums	12–16	12–16	18–25
Lettuce	8–15	5–10	12–18
Tomato Cucumber	20	15–18	21–25

Insulation. It is now considered standard practice to insulate propagation beds and benches; this has the potential of obtaining up to 50 per cent fuel economy.

The suggested procedure is to use 50mm expanded or extruded polystyrene boards. When expanded polystyrene is used, the boards must be wrapped and sealed in polythene. If the beds or benches are narrow then the insulation can be reduced to 25mm on the sides and ends, thus avoiding too much loss of effective bed area.

Where the insulation boards butt up against each other, they should be taped together with 50mm wide self-adhesive cloth tape; this makes a surface for the heated mats that cannot drift apart. The heated mats themselves can also be anchored in position with the same type of tape, prior to covering with sand or capillary matting.

Drainage. In the majority of cases, sloping the polystyrene surface will provide adequate drainage; alternatively drainage channels can be provided along the centre or on both sides of the beds by leaving a gap between the polystyrene board to enable water to drain between them.

Laying the mats. Having established a firm, thermally insulated, base of polystyrene boards, the mats are then unrolled, stretched flat, aligned as required, and then anchored down with tape. If a continuous polythene sheet is used as a cover, this can be tucked in all around the insulation boards. If the mats are to be enclosed in polythene lay-flat tubes this should be of sufficient length to tuck in at both ends.

The mats are delivered to site in the required lengths to match the size of bed or bench, complete with a transformer of a suitable size to match the total electrical load. There is no reasonable limit to the width of bench or bed, but each mat must not exceed 9.6m in length. This means that in long benches or beds the mats are supplied in sections, with the terminations butting up to one another.

All terminations and connections are clearly marked, but it is recommended that the services of a qualified electrician be used to install circuits to the transformers, and connect the mats and thermostat.

Various wattages per sq m can be obtained by careful overlapping of the mats, but any pair of overlapping busbars must always be connected to the same terminal, and for this reason each matching busbar connection is marked with a yellow tab.

When overlapping, busbars can of course overlap busbars, and busbars can even overlap the active heating area, but on no account must active heating areas overlap each other.

CONTROLS

Accurate temperature control is best provided by a thermostat, and it is recommended that this should either be of a capillary type or an electronic type (Table 3). Also, to enable the thermostat to function correctly, it is important that the entire remote bulb or sensor is inserted horizontally into the sand bed or rooting medium. The temperature readings will be inaccurate if only part of the sensor is inserted, or left hanging in free air.

Table 3. Soil warming applications, Energy loadings W/m^2 and type of controls[1].

Soil warming applications	Energy Loading, W/m^2	Recommended Control
Cold frames	55–65 in the south 65–70 in the north	Thermostat control or Restricted hour dosage
Propagation	60–100 in heated houses	Thermostat control
Benches	80–150 in unheated houses	preferred
Heated propagation	60–100 in heated houses	Thermostat control
Beds or floors	80–150 in unheated houses	preferred
Within the greenhouse	80–170 for restricted hours	
Mist propagation beds	170 Minimum	Thermostat control only

[1] See Electricity Council Technical Information Sheet AGR9

If it is decided to operate "Restricted Hour" working, careful consideration must be given to the thermal capacity of the bed, and a possible increase of the energy loading per sq m. In order to obtain maximum use of cheap night rate electricity (Economy 7) a suitable time switch must be included.

CAPITAL COSTS

The capital cost of the heated mats complete with termination is at present (September, 1987) £3 per linear metre run, but it is usual to purchase complete kits, comprising of a suitable size transformer, contactors, and a capillary type thermostat, depending on the size of the installation. Larger installations cost progressively less per sq m, hence:

Size 500 watt kit suitable for $3m^2$ — £100.00
Size 1200 watt kit suitable for $8m^2$ — £200.00
Size 400 watt kit suitable for $14m^2$ — £300.00
Size 2700 watt kit suitable for $17m^2$ — £340.00

ELECTRICITY COSTS

Electricity use under thermostatic control will vary from 0.6 kwh per sq m per day to 2.5 kw h per sq m per day, depending on the differential between air temperatures and the thermostat setting and it is recommended to make as much use as possible of the Economy 7 tariff which offers units at 1.90p for 7 hours between 22.00 and 09.00 G.M.T. against 5.85p for units used during the day.

MODIFYING A DOMESTIC BOILER

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Midland Nurseries, Stratford on Avon, Warwickshire

In September, 1985, an existing glasshouse was converted into a mist propagation unit at Midland Nurseries. After looking at several systems of base heating, we opted for a hot water system, which we would design and install ourselves.

The system. At the heart of the system is an ordinary, domestic 100,000 BTU boiler, fired by liquid petroleum gas. The warm water is heated to about 30°C, and pumped along a flow header. This then feeds a flow sub-header, which feeds four 20mm alkathene pipes, which run the length of the bed. These four pipes turn at the end of the bed, to become four returns. These flow and return pipes alternate in the bed, to give even heat distribution. The warm water from the return alkathene pipes flows into a return sub-header, and from there into the return header, and back into the boiler.

The construction. The flow and return pipes are in copper for the first two metres to and from the boiler, but then change to 50mm P.V.C. pipe. The temperature in these plastic pipes must not be allowed to reach 60°C, or damage will occur. The sub-headers are in 40mm P.V.C. pipe, and the pipe used to heat the bed is 20mm alkathene, connected to the P.V.C. pipe with a screw-on adaptor.

The beds are insulated with 50mm of polystyrene at the base, and 25mm at the sides. The alkathene pipes are placed on a layer of sand, and kept separated and equally spaced by passing through holes drilled in a wooden board. The bed is then topped up with sand, to give a depth of 15 cm. Each bed is 34 sq m and, with seven beds heated this way, we have a total area of 238 sq m of heated sandbed.

Operation and control. At first, the system was operated by the boiler thermostat, which was set at its lowest setting. The pump was constantly running, which had the effect of smoothing out any fluctuations of temperature in the beds. This gave us a base temperature of about 23°C, which was higher than necessary, and a lower temperature was only achieved when outside conditions were extremely severe. To achieve the more desirable base temperature of 15°C, we have fitted a separate thermostat and controller, which takes the average temperature of two probes, which can be placed in the growing medium of any of the beds. This controller now switches the boiler on and off but the pump is left running constantly, to help keep the temperatures in the sand beds even.

Each bed can be switched in or out of the system by a gate valve, which is situated between each flow header and flow sub-header. This valve also regulates the flow of water along each bed, and can

[1] Propagator

be used to raise or lower the temperature of the bed.

Problems. We have experienced two teething problems with the system. Firstly, the ordinary domestic heating pump that we initially installed could not cope with the 1456m of alkathene pipe that is in the system, so a larger industrial pump was fitted.

The second problem was air-locks in the alkathene loops, so each loop had to be bled individually, and a piece of pipework modified to bleed off the air once it was in the return header. Since these two problems have been solved, the system has run without a hitch for the past 18 months.

Cost. The cost of the system, at 1985 prices, was about £2,800, which includes £1,000 for the purchase and installation of the boiler, £1,000 for the sand and polystyrene to construct the beds, and £800 for the pipework.

EXPERIENCES WITH FOUR BASE HEAT SYSTEMS

B. E. HUMPHREY

Notcutts Nurseries Ltd.
Woodbridge, Ipswich, Suffolk

The provision of basal heat for providing optimal conditions for rooting cuttings has been accepted for many years. The phrase "cool tops, misty middles, and hot bottoms", was coined for MacPenny's Mist System at a precursor of these meetings held many years ago at the old Kent Farm Institute in Swanley, Kent.

ENERGY

Costs. In the balmy days of low energy costs the use of electrical heating cables controlled by fairly crude rod type thermostats set on 20°C to 21°C was the order of the day. Today much work, particularly at Efford Experimental Horticulture Station, has investigated the use of lower temperatures than the normal of 20°C, also the provision of restricted heating periods utilising times of low cost electricity availability.

Three other important steps have been taken to reduce bottom heat energy costs: the use of extensive insulation to prevent heat escaping to areas where it is not required; the use of alternatives to electricity which can often result in lower running costs and perhaps most importantly the use of accurate controllers to ensure that heat is only provided where it is required at precisely the right temperature.

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Sources. Electricity is still an important energy source because of its flexibility, versatility, and convenience. Its high running cost compared with most alternatives has been narrowed substantially by the application of the principles discussed above. It normally has the advantage over other methods of being a low capital cost installation.

Cheaper sources of energy such as gas, oil, coal, etc. normally provide basal heat via hot water circulated through pipes of various diameters, though some systems utilise hot air distributed appropriately.

MATERIALS HANDLING

Apart from the need to provide low cost bottom heat there has been an ever increasing requirement for improved materials handling in the propagation area. The traditional propagation bench with its inherent problems of difficulty of access and loss of useable space has tended to give way to either mobile benching or more commonly in Britain propagation beds on the floor of the glasshouse.

The use of materials such as concrete has meant that transportation is not necessarily limited to defined paths, though the use of gantries can give similar benefits of accessibility to all parts of the house.

BOTTOM HEATED FLOORING SYSTEMS DESIGNED FOR MATERIALS HANDLING REQUIREMENTS

System 1. warm water with no-fines concrete. This system was designed before the "oil crisis" but was a response to the increasing cost of electricity and the need for improved materials handling. The basic design features are:

Use of oil as a primary heat source supplying heat through warm water.

Warm water is circulated through polythene pipes to reduce the installation costs and avoid the long term problems of corrosion associated with metal pipes.

The use of 'no-fines' concrete (see below) to provide the advantages of concrete without the disadvantage of lack of drainage.

Construction of System 1. The site should be thoroughly drained with close-spaced (3 metres) land drains covered with washed rejects, brought to the surface, the whole glasshouse area then being covered to a depth of 75mm with 10mm washed gravel.

Concrete headwalls are cast *in situ* with holes appropriately spaced to take 15 or 20mm polythene pipe. Timber battens (100 × 50mm) treated with mould oil are laid at 3m distances across alternate 3.5m bays; 50mm thick slabs of expanded polystyrene wrapped in polythene should be laid on top of the 10mm gravel before placing the battens, to give insulation.

No-fines concrete is placed one bay at a time in alternate bays, finished level with the top of the battens to give a 50mm deep layer. It should be covered with polythene and cured slowly.

Fifteen to 20mm polythene pipe, straightened and pushed through the appropriate holes in the headwalls, is held in position at 125 to 150mm centres by galvanised 'saddle straps' screwed onto the 100 × 50mm battens. Check each pipe run for a leak.

Road forms, or 100mm wooden battens, are placed in position in alternate bays on top of the first layer and no fines concrete placed above the original layer and over the polypipes to a depth of 100mm.

Flow and return manifolds which have been specially fabricated are now placed in position behind the previously constructed headwalls in ducts created between the headwall and the brick work at the gable ends of the glasshouse. Connections are made by pushing the poly pipe onto the spigots of the manifold. This is not an easy operation and it is very important that a water-tight joint is made. Normally this is only possible by heating up each pipe individually and pushing the spigot in while the plastic is soft. It is probably best to have a threaded connector in each spigot and treat the operations of connecting polytube to metal pipe and metal pipe to manifold as two operations.

Connect manifolds into flow and return pipework supplies to the house in the normal way.

Other points on system 1. No-fines concrete comprises 8 to 10mm aggregate with all the fine sand removed. This is then coated with cement for this application, using a strong 6:1 mix. The material produces a honeycomb effect which gives instant drainage. The amount of water added to the mix is very critical; too much and the cement runs off the individual aggregates; too little and the cement fails to coat each aggregate properly.

It is best to add water on site as the material sets very rapidly (say 30 to 45 min.) and you need plenty of people to lay the material. Laying requires some care as the surface must not be trowelled over for there is a real danger of producing a skin of cement on the surface which prevents drainage. The material may be moved by shovelling or raking and the final finish is produced by pressing into place. A roller is a good tool for this job.

No-fines concrete provides such excellent drainage that in practise it is necessary to blind the surface with a layer of sand brushed well in.

Water temperature is critical for polythene pipework. Polythene pipe will not indefinitely withstand water at boiler temperature and it is normal to use temperatures around 38°C. It is always advisable to consult a heating engineer on the best ways of achieving this but there are at least three possible methods:

1. Use separate boiler for the bottom heat installation and run it

at the required temperature. As this is likely to cause damage to the boiler eventually it is usual to use secondhand boilers for this approach.

2. Use an appropriately rated calorifier. This provides the safest and most reliable approach.

3. Use an appropriate mixing/proportioning valve. This is normally cheaper than a calorifier and modern valves are highly reliable. A "fail safe" system must be incorporated which prevents water that is too hot being fed to the system in the event of a mixing valve breakdown.

System 2—Warm Water From Solar Panels. This system was designed after the oil crisis and took into account the need for good energy conservation by using low cost energy and providing lower thermal inertia (response to heat or cold requirements) than the no-fines concrete system.

Constructional details are similar to System 1 up to the provision of polystyrene insulating slabs. Above the slabs are laid Robinsons Polypanels. These are in effect solar panels manufactured for heating swimming pools, etc. and comprise hundreds of small channels or tubes fabricated from polypropylene and built up into sheets approximately 8mm thick. Each 1.2 m wide sheet is welded onto a header pipe (manifolds) which provide the source of supply for water which is circulated through the sheets. Sheets can be made from 3m (standard) up to 7m long according to particular requirements.

Polypanels are laid side by side, as required to cover the area, the manifolds connected by suitable short connecting pipes to provide a ground level (they could be used in a bench, of course) source of bottom heat. To protect the panels and provide a reservoir of moisture a layer of capillary matting is placed over the top and the propagating receptacle is placed on this.

As with System 1 water temperatures should not exceed 38°C.

Materials handling in this system is dependent upon gantries, because although the polypanels can be walked on—and in practice over a period of nine years have proved tough and durable—they will not withstand heavy traffic.

System 3—Warm Water and Sand. This system is a modification of System 1, the no-fines concrete being replaced by carefully compacted sand of the grade recommended for capillary beds. Well compacted sand is remarkably stable if not too wet and it may be possible to traverse such a bed with a mechanical vehicle, though it is unlikely it could withstand a forklift truck.

In one installation I have seen Mypex is used as a cover over the sand. This may break the capillary connection between the sand bed and the rooting receptacle. An alternative approach may be to bury an industrial membrane such as Terram about 25mm beneath the surface. This would give strength and stability to the sand without losing the valuable benefit of capillary connection. It is likely that a gantry system is required for efficient materials handling with this type of construction.

System 4—Warm Water and Concrete. Replacement of no-fines concrete by conventional concrete provides the ultimate work surface and the greatest flexibility in materials handling. The thickness of concrete can be reduced to 100mm and it must be laid to careful levels to provide sufficient falls for good drainage into gutters. The system has much to recommend it but of course provides no capillary "pull" to drain rooting receptacles. This can be quite a disadvantage in the late autumn period under mist when some of the newer rooting/growing media used in direct sticking can become very wet.

COSTS

It is very difficult to give meaningful costs at a given moment in time. Prospective users are urged to make their own investigations. The most expensive system is likely to be the Polypanel system where prices as high as £35.00 per square metre for the panels alone have been quoted. An equivalent price for 20mm pipe to cover the same area would be £6.00.

No-fines concrete is some 10 to 20 per cent cheaper than conventional concrete but this saving is lost if the thinner 100mm thick slab of conventional concrete is used against the 150mm no-fines slab. Current costs of no-fines is approximately £3.70 per square metre (September, 1987). Polystyrene slabs, common to all installations, are approximately £2.50 per square metre.

A no-fines system without polystyrene insulation installed in 1976/77 cost £11.08 p per square metre and the Polypanel system, which included polystyrene insulation and was installed in 1978, cost £18.50 per square metre.

The no-fines concrete installation will carry substantially higher labour inputs than most of the other systems though the sand beds may be close in final labour costs. The Polypanel system will almost certainly carry the least labour inputs and, unlike the systems using concrete, any mistakes can normally be rectified.

OBSERVATIONS ON NURSERY STOCK MANAGEMENT IN NORTH AMERICA

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These observations on nursery stock management in North America were made during a visit there in September, 1986, as recipient of the Great Britain and Ireland Region's Mary Helliar Travel Scholarship award.

During the six week trip, which began in Boston, Massachusetts, and finished in Olympia, Washington State, I travelled some 7,000 miles and viewed 20 production nurseries in reasonable depth. The nurseries, of varying size and composition were selected to provide a cross section of approaches to contrast, compare, and make comment on.

COMPANY POLICIES

The product line. Generally speaking, production nurseries in the United States grow a more specialised product line than is the case in the U.K. Plants are put into production more because they are commercial than because they are choice. This is not a recent trend but appears to be a combination of tradition and company policies which reflect current market trends and production capability. A product range of 300 to 500 lines would be fairly representative of many nurseries I visited. Compare this with the trend in Britain towards greater specialisation.

Diversification into growing a wide range of plants which require markedly different growing regimes can place undue strain on production efficiency. Administration and production costs may rise as more stock plants and growing facilities are required. Labelling and stock control become more complicated and as a company diversifies marketing costs rise.

Despite these shortcomings diversification can provide a nursery with some buffer against possible shifts in market trends which can leave the more specialist grower more vulnerable.

Buying policies. Some 75 per cent of the nurseries I visited implement a buying policy and most usually this means liners and young plants bought in for growing on, often in response to shortfalls or crop failures. Many nurseries on the east coast and in the mid-west states, regularly buy in their tree whip requirements from the more specialist producers on the west coast, such as Schmidts of Oregon. Understocks and tissue culture plantlets are also commonly bought in.

[1] I.P.P.S. Mary Helliar Travel Scholarship Recipient, 1986.

Economics and convenience are the main reasons behind buying in, though such a policy brings with it other advantages such as allowing nurseries to capitalise on stock surpluses, rather than adding to them through their own over-production. Also, where production resources may be limited, buying in selected items rather than growing them allows these resources to be put to better and more effective use.

Contract production. This approach is perhaps more evident in Europe than in the United States, where the use of a secondary grower producing selected items on a contract still appears to be fairly uncommon. I found this a little surprising, especially for the larger growers experiencing heavy demands on space (in particular protected space) where the use of another grower's facilities and overheads, if applied sensibly, can bring considerable advantage. In the U.K. the technique has become more widespread as more glass-house space has become available for nursery stock following the departure by many growers from traditional salad and cut flower crops as heating costs continue to rise and competition within the EEC intensifies.

Quality and customer service. Quality of production and efficient customer service appeared to be emphasised on the nurseries I visited, even on the larger operations where a uniform and consistently good quality product may be more difficult to achieve. This positive attitude has doubtless been encouraged by the competitive market which now exist in the United States. This competition has been intensified by the recent departure of many growers from the older ball and burlap production in favour of container growing as the garden centre sector continues to expand, augmented by the greater interest currently being shown in nursery stock by the larger multiples.

Health and Safety. As in the U.K. there is an increasing awareness in the American nursery trade of the importance of sound health and safety practice. In the past standards may have been a little inconsistent, with attitudes fairly indifferent, especially to machinery and pesticides handling. But recent legislation in the United States has led to the introduction of the "Right to know" law. This has made all employers legally obliged to inform all employees of potential work hazards. Nursery staff must be briefed fully and instructed correctly in safe working practices and be provided with all the requisite protective clothing and equipment needed to operate safety. Employers now have a legal obligation to keep all staff up to date and informed fully about health and safety matters.

Forward planning. I was interested to learn how nurseries approach the forward planning of their production departments and for this purpose I devised three categories:

Short-term planning: up to 12 months ahead

Medium-term planning: up to 5 years ahead

Long-term planning: up to 10 years ahead

Most nurseries I visited did some form of short term planning such as the organisation of work schedules, allocation of labour, job planning, ordering of materials, etc.

Medium and longer term planning was not so commonplace. Of my visits, the most notable exceptions to this were Studebaker's Nursery (Ohio) whose production and marketing strategy is centered around a 5 year plan which is constantly reviewed and updated as necessary, and Monrovia Nursery Company (Oregon and California).

Monrovia is currently looking to expand its production and due to its present base in Azusa, California, being in a land-locked situation has recently considered a new and larger site (625 ha) in nearby Ventura County to replace it. The transition is to take place gradually with the minimum disruption to production and customer service. A long term plan outlining the phased approach to the move has been drawn up, which will act as a target to work to and provide a timescale so that the transfer of resources between sites is completed smoothly, on time, and with the minimum of disruption.

The Studebaker 5 year plan is a flexible framework in which to plan production and marketing. It is reviewed annually and updated as production performance or sales trends change. The nursery sets out work targets for some tasks and productivity is monitored tightly. This involves the use of a work study exercise known as 'Required efficiencies'' through which realistic work targets are set for measured jobs such as potting, cutting preparation, or staking and tying. A bonus is paid to staff where these targets are reached or exceeded.

A well planned approach to costings and budgeting is also evident and is based on the use of capital and revenue type systems. These are linked to projected sales and productivity figures and comprise an integral part of the 5 year plan. Each department manager receives a weekly computer print-out of their allocated labour budget and each month the production director uses a similar print-out detailing information on work performance related to budgets, then this is used to monitor financial status and work progress.

Management structures. This refers to the way responsibilities for crop production and management are divided and the criteria applied to their selection. For production to be efficient and competitive a nursery must be organised to make maximum use of the skills and resources available. An effective way of achieving this, particularly with high volume production, is to implement a departmental management system. Here, the nursery is sub-divided into sections, or mini-nurseries, with a supervisor in charge of each.

Monrovia Nursery Company is well known for its successful adoption of this approach. It has worked very effectively with its exceptionally high volume production—currently 40 million saleable units on 330 ha in Los Angeles, California, with a further 12 million in Dayton, Oregon. With this method each division supervisor is responsible for watering, pruning, spacing, stock control, weed control, lifting stock for sales, and plant protection. The advantages of departmental management are:

It encourages the grouping together of plants with similar cultural requirements, i.e. shade, nutrition, water regimes, and space, and this simplifies crop management.

Stock control becomes clearer and less complicated.

It allows the development of more specialist growing knowledge.

As a result there may be greater competence in practical skills as staff become more familiar with a specific group of plants.

It follows that plant knowledge should improve and the quality of the finished plant is likely to be of a higher standard.

Management responsibilities become more clearly defined.

Nursery staff may be encouraged to take greater pride in their respective sections, and so keep the nursery clean and tidy.

A more varied work schedule for nursery staff will tend to reduce repetition and monotony, raise morale, and perhaps lead to higher productivity.

Other nurseries using a similar approach include Iselis (Oregon) and Greenleaf (Oklahoma and Texas).

Labour and training. Obtaining consistently good labour for nursery work has never been easy. Once recruited it can be equally difficult to keep on a longer term basis and this is a problem common to many nurserymen. In this respect America experiences similar problems, being heavily reliant on migrant labour, largely unskilled, for its main workforce. Nurseries in the mid-west and on the east coast draw regularly on local Puerto-Rican (and more recently Cambodian) labour and west coast nurseries rely largely on local Mexican labour.

Some nurseryman prefer this arrangement, some do not and it has advantages as well as shortcomings. Labour is cheap and plentiful, always available and there to be used, sensibly or otherwise. It is consistent, returning each year to the same nurseries, usually between March and December. The more capable often progress to supervisory positions and often become crew leaders.

Low cost seasonal labour is particularly convenient for large scale production as much of the work is monotonous and labour intensive and—with skilled supervision—fairly straightforward. American nurseries generally grow a less diverse range of plants than in the U.K. and this to some extent simplifies matters.

The shortcomings of using unskilled staff are often overcome by using contract labour. This is a widespread practice for seasonal work such as field budding and rootball digging, much of which continues to be done by hand. This is cheaper than employing full-time labour and is highly skilled and productive because it is so specialised. It is also there as needed and does not have to be kept occupied during quieter periods. Contract budders and diggers are most usually paid piece rate.

Despite the low cost convenience of migrant and contract labour some American nurserymen are now concerned about the apparent shortage of skilled labour available to the nursery trade. Leading growers are looking to the adoption of apprenticeship schemes and nationally co-ordinated training programmes to help remedy this. Some feel that current training is too academic and does not meet the more immediate practical needs of the trade at technician and middle management level.

TECHNICAL OBSERVATIONS

The American nursery trade, like Britain's, has witnessed continued expansion in recent years. Current valuation of the nursery stock industry in the United States stands at around $5.3 billion at wholesale prices. The contribution made by the container sector is steadily increasing as garden centres continue to expand, landscapers undertake more summer contracts, and the DIY multiples become more informed and show a greater commitment. In the U.K. it is estimated that the nursery trade handles around 120 million containers a year and American production is currently put at 15 times that in volume.

Technical aspects of production remain quite basic though. Generally, propagation systems are less sophisticated than those found in Europe where, perhaps, more difficult-to-root plants are grown. Conventional mist systems appear standard throughout American nurseries and direct sticking is used only to a limited extent though this may change as cell systems become more affordable. Polythene standing bases with overhead irrigation are the main growing regime and capillary beds with low level system appear uncommon. American product lines are generally less diverse and these simpler systems appear to meet most present needs. Surprisingly, many growers did not appear familiar with the capillary bed system or its benefits and those that were had been discouraged by the higher capital costs involved. Rigid containers with side slits or mesh bases assist greatly with drainage as do the fairly high levels of bark (30 to 60 per cent) used in some mixes.

As in the U.K., rigid containers appear to have almost completely replaced polythene bags and largely for the same reasons: ease of handling, appearance, and customer acceptance.

Composts. Composted bark, peat, and sand are the main bulk ingredients; the inclusion of bark varied from levels of 20 to 60 per cent. Many growers include hardwood bark in their mixes, either instead of, or in addition to, softwood bark. For some nurserymen the former is more readily available and so with lower shipping costs is cheaper. It is also thought to contain some micro elements and to contain certain pathogens believed to control, to some extent, phytophthora.

It decomposes much faster than softwood bark, probably because of its higher cellulose levels. This can result in considerable volume loss and the ideal balance probably lies in combining the two types in the mix. Generally a much coarser grade of bark is used than in the U.K. and mixes appear to be either very open with high porosity or quite heavy with a poor air:water balance.

Monrovia and Princeton nurseries incorporate pasteurised loam into their mixes to provide some buffer against extremes of pH, moisture, and salt levels.

Osmocote continues to be the main controlled-release fertiliser used though surprisingly few nurseries incorporate this at the mixing stage, preferring to add the Osmocote as a top dressing after potting. Reasons for this are:

Long standing periods which may lead to damaging salt levels through build up of high compost temperatures.

Mixing gear remains somewhat basic, resulting in physical damage to the resin coats.

Inadequate mixing facilities leading to mixes which are not uniform.

A technique known as "dibbling" may help overcome these problems. This involves placement of the fertiliser granules immediately beneath the rootball at potting as opposed to the current practice of applying Osmocote as a top dressing. This approach minimises high salt levels, avoids uneven distribution, and allows fertiliser to be placed in the immediate vicinity of the root and is available as required. It appears to have potential, though application rates must be accurate to avoid root scorch problems.

Stock plants. Few nurseries appear to use selected stock plants as a source of propagation material, electing instead to obtain it from saleable or growing stock on the nursery. This appears to meet most needs and the costs involved with stock plant management coupled with land inevitably tied up has so far discouraged the widespread use of stock plants.

Direct sticking. Not widely adopted so far and of the major nurseries I visited, only Briggs Nursery, Olympia, Washington was showing any commitment to the technique, currently producing some 150,000 pots each year, mainly 4 litre, using 3 cuttings per pot. If the limiting factors of extra space and propagation material can be overcome then for the easy-to-root items, direct sticking does confer considerable savings in time and labour input. To a certain extent there exists a transfer of labour input with direct sticking from the potting stage to the propagation stage. It is ideally suited to the easy-rooting, quick-growing, cheaper items such as *Ribes, Forsythia, Philadelphus, Potentilla, Euonymus, Hypericum,* and *Spiraea,* so the range of plants grown is also a determining factor in whether this approach is pursued.

At Briggs Nursery the direct sticking method has been refined well to minimise handling and labour. Pots are filled with compost on a potting machine with cuttings being inserted as pots come off the conveyor. This is done centrally in one shed and all materials are close to hand. Cuttings are made expediently using secateurs to prepare only best quality material. Basal leaves are not usually removed. Prepared material is set down in unheated single span polythene tunnels and overhead spray-lines maintain the required humidity. Mainstream sticking is done in June and July and rooted material is grown on to produce strong, well-rooted plants for overwintering. The following spring plants are trimmed to get good basal branching and sold later that year.

Cell systems. Some American nurseries, usually the more specialist, are moving over to using cell or plug systems for propagation. In addition to minimising transplant stress, cell systems can provide savings in time, handling, and labour. Ground cover and herbaceous specialists in particular are looking to cell systems where automatic box filling and direct seeding equipment expediate work still further.

Cell systems, though initially aimed at the bedding plant sector, have developed quite rapidly in the United States and it has been estimated that over 1.5 billion cells are produced each year. Nutrition, irrigation, humidity, and seed quality are the most critical aspects of successful production. Fog systems have been found to provide a constant and even humidity needed for seed germination and rooting leafy cuttings. Waterlogging and leaching are also avoided. High seed germination and good rooting performance are essential for efficient use of cell systems. Seed and cuttings, therefore, should be of the best quality.

Tissue Culture. The use of tissue culture for propagating woody ornamentals continues to be a growth area of the nursery trade. Of the 10 larger nurseries I visited, 5 had installed their own tissue culture laboratories and each gave similar reasons for doing so:

It allows the propagation of disease-free material.

It is a rapid propagation technique useful for bulking up new introductions, choice plant material, and in maintaining stocks for which there is a consistently heavy demand.

It offers an alternative means of propagating difficult-to-root woody ornamentals such as *Rhododendron, Kalmia,* and *Betula.*

Plants propagated by tissue culture demonstrate good growth habits, with basal branching, producing well-shaped plants because of the shorter internode length.

It obviates suckering and incompatibility problems associated with traditional grafting techniques.

It is quicker.

Nurserymen also expressed the same reservations—largely economic—as tissue culture continues to be an expensive propagation method, with high capital and running costs.

The range of plants produced in this way were similar throughout and included some difficult-to-root woody ornamentals such as *Rhododendron, Syringa, Pieris, Stewartia* and *Fothergilla;* new introductions being bulked up and, usually in response to heavy demand, plants which require rapid propagation.

Briggs Nursery, which has largely pioneered tissue culture of woody ornamentals, interprets the technique as a tool of propagation. It is dependable, predictable, and unlike more conventional methods, is not subject to the vagaries of climate and season. It gives the nurseryman the benefit of all year round propagation in a sterile and controlled environment.

Monrovia estimates that at present it is breaking even with costs on tissue culture so contract growing arrangements are favoured to streamline production and give smoother cash flow. The need to consider costings critically before placing a plant into production was emphasised throughout and, for commodity items, a multiplication rate of 1 × 10 may be the minimum acceptable for propagation to be economic in this way.

Successful weaning of tissue-cultured material requires great care and attention as, unlike conventional cuttings, plantlets possess thinner cuticles and stomata, and have underdeveloped root systems. At this stage they are especially sensitive to moisture and temperature extremes.

Apical meristems (shoot tips) are thought to provide the best explants, being genetically uniform and less likely to produce off-types than other cultures.

For the future the financial aspects will, I suspect, continue to provoke most concern. Because of the high costs involved tissue culture is likely to continue for the present, at least, as an alternative to conventional methods, as opposed to replacement.

WHY NURSERYMEN SHOULD NOT PROPAGATE PLANTS

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Kilcock Co. Kildare, Republic of Ireland

Starting a nursery is a daunting task. You have an ideal that you want to achieve. In reality the ideal is postponed to a long-term ambition. Some preconceived advantage such as horticultural training, nursery skills, or the ownership of land may give birth to the idea of setting up in business, but the new nurseryman quickly finds that he labours under many handicaps: lack of capital or markets, growing facilities, labour, or even not enough hours in the day. Alone he has to build, propagate, grow and sell—tasks which are departmental responsibilities in larger nurseries.

Is it not surprising, therefore, to learn that 50 per cent of all new businesses fail within five years? Those that survive the first five struggle on for a few years more. The accepted business wisdom is that successful companies rarely show successful characteristics in the early stages. Most come about in the seventh or eighth year.

One attribute of those successful in new ventures is their ability to analyse their business environment and to put their limited assets to best use. Table 1 shows the profitability of 6 large nurseries scattered throughout the U.K., each with a minimum turnover of £1.8m. Only one has acceptable profits on sales and returns on capital employed, to offer encouragement to a fledgling nurseryman.

Table 1. Profitability of six nurseries in Great Britain, 1986.

	A	B	C	D	E	F
Sales	£2.9m	—	£1.8m	£6.2m	£3.5m	—
Profit	£32,000	£93,000	£39,000	£72,000	£52,000	£140,000
Capital employed	£1.2m	£800,000	£285,000	£1.3m	£560,000	£575,000
Percent return	(2.3)	11.63	13.68	5.54	(9.2)	24.3

Source: Annual Reports, 1986, Companies House.

A young entrepreneur may find it difficult to relate to a sales figure of £1m plus. The main lesson to absorb from an analysis of these figures is that the nursery trade is an asset-rich and a cash-poor business. In other words, any available cash is likely to be tied up in stock and the provisions of facilities to grow and maintain the stock. Therefore, capital must be allocated carefully to ensure it is used to the maximum benefit of the business.

Perhaps profit is not the motivation factor in setting up a new nursery, nor possibly the yard-stick to measure progress or development. The nursery trade is described as "A Way of Life" for many, rather than a business. The findings in a recent survey of 1200 new businesses (Table 2) shows that the profit motive ranks lowly as a reason for setting up on your own.

Table 2. Motives for the Foundation of a New Business

Desired independence	25%
Redundancy	18
Job insecurity/risk of unemployment	12
Specialist knowledge	11
Disagreement with employer	11
Product development	8
Own previous firm's closure	5
Financial incentive	4
Other	6

Source: Binder Hamlyn Chartered Accountants Survey of 1200 New Businesses, Dublin 1986.

A common failure is for the owner to invest the limited capital, or devote excess time, to his prime area of interest, rather than to what the business requires—those jobs critical to the establishment of the business.

The title of our own Society, may provide a clue to where the true interests of nurserymen lay. Propagation is a fascinating and in many ways a glamorous topic and much more exciting to talk about than such mundane matters as how to trim, shape, and grow plants properly. Fewer still will discuss marketing. Nurserymen either shrug in incomprehension at such a topic or avoid it with disdain as a subject not worthy of their attention.

If a new nursery owner commits his capital in accordance with his interest in propagation rather than selling for example, then the investment may be quite inappropriate to his needs, and will cause the failure of his business.

In establishing a new business a nurseryman has four primary operations to carry out: building, propagation, growing, selling. It is virtually impossible for a small nursery to do all these operations successfully, with limited staff, skills, and capital. The realistic approach, therefore, is to shed and sub-contract some of the operations. A nurseryman must grow good crops in order to sell them and he must devote time to selling so that he understands what the market requires. The most time-consuming and demanding operation is propagation and this should be sub-contracted out.

The nursery industry is under developed, poorly structured and inefficient. It has never been subjected to the shock therapy that the oil crisis of 1973 applied to the houseplant trade. Oil prices forced up production costs, the growers found resistance to increases in sale price, and so in the squeeze only the fittest survived.

The survivors are profitable and efficient producers. The houseplant trade is much more aware of the need to specialise, of crop throughput, the utilisation of space, and grade-out. Consequently, the propagation, growing, and distribution of plants are now separate but interdependent sectors of this trade.

This degree of specialisation does not exist in the hardy nursery stock trade. Therefore, the new nurseryman is more likely to take on more tasks than he can handle, rather than plugging into a structured market system and finding a particular niche in it that he can serve; something he could readily do in the houseplant trade.

It is particularly important in the early years that new nurseries devote as high a proportion of their available capital as possible to stock and minimize their investment in non-productive assets. Table 3 shows the ranking of ingredients needed for success from a survey of the same 1200 new businesses listed in Table 2.

Table 3. Ranking of Ingredients Needed For Success

1. Market knowledge.
2. Adequate capital.
3. Management ability.
4. Determination.
5. Curtailing Your Standard of Living.

Source: As Table 2.

Market knowledge is shown to be the first requirement for success. Therefore, growing the right quality for the market and learning what the market requires, and responding to it quickly must be the strategy for young nurseries, rather than tinkering around with propagation problems. It is financial lunacy to prejudge the market and invest blindly in mother stock. The capital tied up in the propagation facilities is more wisely spent in procuring young stock and turning these into cash, learning more about the market and building up the capital base.

Table 4 summarises the management and financial disadvantages of home propagation. As in the houseplant trade, nurserymen who place all their propagation requirements on contract enjoy the advantages of not having to invest in buildings or mother stock, being able to concentrate on growing and selling with no distractions, avoiding overproduction because of planned growing, and having a quicker response to market changes.

Table 4. Management Disadvantages of Home Propagation

Investment in motherstock.
Investment in facilities.
Slower response to market changes.
Less disciplined growing.
Poorer timing.

The following are the disadvantages of home propagation observed as a consultant to other nurseries over a 10 year period: easy lines overproduced; difficult lines underproduced; small quantity lines ignored; discontinued lines continued; numbers deficits made good with easy lines. Young nurseries rarely have the ability to control propagation tightly enough to avoid these pitfalls.

In the houseplant trade it is relatively easy to source the young material. However, there are few specialist propagation nurseries in the hardy nursery stock trade and those that exist do not provide the same level of service nor offer the same competitive prices where comparisons can be made with houseplant producers (Table 5).

Table 5. Sources of supply for young plants. (Price comparisons (in pence) 1987).

	House plants	Hardy stock
Cordyline australis	28p	35p
Hedera 'Gold Heart'	14	23
Fatsia japonica	28	44

The concept of delivering requirements or components 'just in time', is now an integral part of many major industries such as car assembly, electronics, and even the houseplant trade, but it does not exist in the nursery trade.

In advocating a policy that nurseries should not propagate, a weakness in the argument is that there are not sufficient specialist propagators who will provide the material required in the quantity required, at the time required. Although some can supply the material required, the quantity, price, and time of delivery all have to be improved.

It seems inevitable that we must follow the trend established in the pot plant trade of segmenting the production process and specialising in a particular segment. Table 1 showed the poor financial results of large general nurseries who involve themselves in all activities.

I am sure if similar financial figures were available for specialists nurseries these would show a more profitable trend. The fastest growth and the highest return on investment must come to those nurseries identifying niches in the market and pursuing and applying their capital to servicing that market. The day of the generalist nursery with low profitability may be coming to an end.

WHERE HAVE ALL THE PROPAGATORS GONE?

SAM MACDONALD

Barguillean Nurseries,
Taynuilt, Argyll, Scotland

Last year Barguillean Nurseries joined the queue for a top class plant propagator. We had high expectations when we ran advertisements in the national trade press. Two months later and almost a £1,000 poorer we drew a blank. Three advertisements had drawn five applicants—none of them suitable—and all of them glaringly underqualified.

Thinking that the right candidate might not have applied because, let's face it, who wants to travel 400 miles north to the backwoods for a job. We re-wrote the advertisement and placed it again without the banner of Barguillean, simply inviting the right man or woman to name a salary and apply to an anonymous box number. In fact, the advertisement sounded very positive and we were bitterly disappointed with the response. Three replies. Same story.

Curious about the lack of response and anxious to see whether other nurseries had had similar disappointments, I contacted David Clark at Notcutts and John Hedger at Fargro, along with several other nurseries that I approached informally on the topic. The story was the same everywhere. Poor response to appeals for propagators, and even Notcutts, with the prestige of a company of its size, had received only four replies to an advertisement for an assistant propagator in July last year.

Further research led to widespread feeling of concern about the situation and, around Christmas time, John Costin suggested that I do a little more work on the subject and present my findings to the present Conference.

It sometimes helps to start at the beginning and during my research I studied the IPPS G.B. & I. register of members to establish exactly what standing the propagator has within the Society. As a quick look at the breakdown of the membership reveals 7 per cent of the membership describe themselves as propagators (Table 1). We are rapidly becoming a professional rather than a craft-oriented Society with increasing numbers of members in the academic, advisory, and technical areas.

Many proprietors, managers, and foremen may well have moved up through the ranks of nurserymen/propagators to the level they are at now but nevertheless the picture clearly reveals a strong movement away from the craft level. If there is a serious shortage of skilled propagators in the industry—now being described as one dependent on mere 'stickers of cuttings' rather than truly skilled propagators—could we look further and try and identify some of the

Table 1. IPPS G.B.&I. membership category breakdown. Total Membership, 442.

Professional Categories			Nursery Categories		
Academics	69	15%	Proprietors	61	14%
Advisors	26	6	Directors	56	12
Technical staff	17	4	Managers	52	11
Research staff	6	1	**PROPAGATORS**	**31**	**7**
Micropropagators	3	0.6	Foremen	23	5
Consultants	3	0.6	Nurserymen	19	4
			Partners	17	3
TOTAL	123		TOTAL	259	

causes for the change?

In May of this year I prepared a short questionnaire and researched the companies which had advertised for propagators over the previous 14 months. Delving through the advertising pages of the trade press enabled me to identify them and I found that 36 nurseries, local authorities, and some National Trust properties had advertised. *The questionnaire was sent out to all of them and I* received a 40 per cent response. The questions covered a wide range of interest but, in particular, looked to establish what responses the advertisement elicited, what pay was offered, and what responsibilities were involved. What shortages of skills were revealed in the replies, what status the propagator enjoyed and whether it had decreased or increased in the last 10 years. It also covered training and what suggestions employers could make to bring about some improvement.

Some of the salient points from the replies are summarised below:

How many replies did you have to your last advertisement?
Average: 6.6 (One local authority had 25)

Did the respondents have the skills you required?

Yes	15 per cent
No	85

Rates of pay offered?

4–6,000	31%
6–8,000	49%
8–10,000	19%
10,000 +	.05%

What shortfalls in skills did respondent reveal?

Experience	75%
Plant knowledge	24%
Propagation skill	24%
Business know-how	13%
Enthusiasm	10%
Staff management	14%
Quality Control	13%

What further comments do you have on the quality and experience of the applicants?

"In 23 years we have had applications from only 2 propagators . . ."

'Too many people think propagation is easy''

'Poor wages in the public sector probably the reason''

'No applicants because of the expense of living in Surrey''

'Lack of practical experience in a wide field''

'We felt that to find an experienced, motivated person who would fit in here would be difficult and would demand an unreasonable salary . . .''

Do you have any suggestions as to how to tackle the shortage of propagators?

'Better training . . .''

'Colleges to pay top salaries for propagation staff''

'Often the talent is about but you have to be able and willing to pay for it . . .''

'Teach propagation as a specialist subject such as accountants get specialist instruction . . .''

'You have to pay them too much to get them to Guildford''

'More money would help''

'Not enough time is given to young staff to enthuse over plants and how to multiply them.''

'Train your own and keep them away from colleges.''

'Better pay and status plus more job satisfaction''

Explain what you perceive as a fall in interest in propagation over the last 10 years.

Increase in interest—	Only one respondent
Decrease seen—	95%
No change in 10 years—	4%

Comments

'I believe its a very serious fall''

'Opportunities in other departments now greater . . .''

'Most young people are motivated by the wish to drive and want jobs with tractor driving involved:''

'Young people go for higher paid jobs. Propagation is seen as boring.''

'There is easier money to be made in other areas of horticulture.''

'Government cut-backs have resulted in poor wages''

'Jobs in horticulture are for the laggers at school: statements as, 'I feel you would be best suited to a job in gardening or horticulture . . .' ''

'The industrialisation of amenity and ornamental horticulture has killed the green-fingered mythology . . .''

What sort of training programmes do you offer propagators?

No training at all	31%
Some in-house training	39%
Day-release	26%
Other forms of instruction	4%

What level of status does the propagator enjoy?

75 per cent felt he or she enjoyed a high level of status, and that it was: the most rewarding job on nurseries; the most creative position; the most interesting job; requires the best skills and discipline.

Earlier this month I spent time travelling around Britain combining a sales trip with meeting IPPS propagators in the evenings to find out their side of the story. The picture here is very similar. There is a general feeling that interest in the propagation department has fallen off, and as plant range has contracted over the last 10 years skills have deteriorated. A number of propagators commented on how little training is offered, particularly at colleges where only "propagation principles" are tacked on to parts of other courses. In far too many cases propagators felt themselves isolated from the nursery, cut off to the point where they had no say in the way the nursery was run and developed and were rarely consulted.

There is a widespread misapprehension about the impact micropropagation is going to have. The prestige the traditional propagator used to enjoy has been eroded by micropropagation and direct sticking, which is gaining in popularity, as well as streamlined production and, industrial techniques among the largest and most prestigous nurseries in the country whose ranges of plants have contracted.

This insecurity is increased further by the development of the specialist nurseries who are now filling the propagator 'skill gap' by becoming producers of large quantities of rarer items as liners and rooted cuttings. The more propagators I spoke to the harder it was to escape the feeling that morale is very low but also a feeling that the image of the industry as a billion pound sector of the economy clashes dramatically with the realities faced by those at the top in the craft sector. Look around today at some of the high-tech equipment on display and see the scale of the resources being thrown into the propagation house. Doesn't it contrast sharply with the feelings of the men and women who work with the equipment, and shouldn't we be taking more account of their feelings and developing ways to involve them more creatively?

It is, perhaps, a good time to move to specific cases to try and flesh out the subject. To highlight some of the points, I have summarised a profile of three propagators around the country—two involved in very large companies, one from a more modest outfit.

Let's take Bob, who works at Hillside Nurseries. I have substituted new names to protect their identities, but Bob is a case in point.

Bob joined the company in 1962 on the then standard wages of £4.8s per week. He has been with the company for 25 years and has served with exemplary loyalty. He has risen through the ranks to the position of head of one of their propagation sections where he is responsible for the production of 1.2 million cuttings per year and for the supervision of a staff of 12. Curiously Bob is depressed about his work and feels let down by a feeling that he has no where else to go in the company and has a sense that there is nothing left to aim at. He feels neglected and out of touch from a lot of what goes on around him and complains that he is not involved or consulted in planning. Yet he has been informed that the company intends to increase production by 40 per cent over the next five years. Despite this general uneasiness and frustration Bob turned down a job offer from a local parks department, despite a 30 per cent increase in wages, for no other and no more significant reason than he "just likes the work here . . ."

Bob's current salary is £9,800 with few perks or bonuses. However, he did have a letter from the company last Christmas thanking him for the work he had done during the year!

According to figures supplied to me by the Low Pay Unit in London the average manual worker pay packet is £207.50 per week. Need I remind you that Bob has worked for a company which from the last set of accounts I was able to lay my hands on through Companies House turned over more than £6.2 million, and remember he has worked for them for 25 years and is occupying a very reasonable position yet he is being paid less than the average manual wage. Surely this sounds unusual? It is not. Let's take another case:

Pete joined Highbury Nurseries on an apprenticeship scheme in early 1975 and in the three years since has worked in all departments and managed to fit in a HNC at Hadlow in 1979–80. Following what he called the "Highbury bust up" Pete was asked to stay on and offered the head propagators job and a tied house on £76.00 week. He is currently responsible for one full-time and two part-time workers and is asked to produce only 75,000 ericaceous plants per year. I say only because he would like to do more and feels he has the staff to do it but not encouraged to think that way. Pete's feelings about the job are negative. He's upset about the leaking facilities in the propagation house and claims that no one is interested in what he does. He gets little encouragement, is supervised by a former sales representative, gets no support from the family that owns the nursery and feels he is working for a company that has lost its way and its will for expansion. He says he feels he is not involved at all, and that targets of production are so low he sits around for months pretending he is working. Pete currently earns £125.00 per week which if you remember is also a long way short of the average manual wage packet of £207.50.

At Valley Nurseries I spoke to Dick. He came to Valley after his family's rose business was taken over by a larger concern. He graduated in 1985 from Bath University where his contemporaries considered it astounding that he was giving up the chance to earn what they called "real money" by going into the nursery stock sector which, between 1969–1983 claimed less than 8 per cent of the Bath graduates, confirming yet again that we live and earn our living in the least glamorous and most poorly paid sector of horticulture. Notcutts and 30 other companies incidently turned Dick down as "overqualified" thereby making another striking comment on how employers see their future.

Dick started in propagation and has remained there. He is now one of 15 supervisors in a company producing more than 2 million plants a year. He has just been appointed to plan, supervise, and run a £20,000 microplant unit for Valley Nurseries. He feels very positive about the company and the opportunity he has been offered. However morale varies from department to department and Dick feels that the path for increased production has been done at the expense of health and safety and that despite regular manager meetings there is a feeling that more could be done to involve the supervisors in the planning.

Dick will be appointed to his new position with a full degree in horticulture and with good mathematics and computer skills on a wage of £144 per week which didn't sound too good to me but he says he accepts it and that the company has a reputation for pushing the high fliers on at a good pace once they have established themselves. Nevertheless, that £144 per week when added to the qualifications of a university graduate match poorly with that average wage of £207.50 for manual workers.

I have spent a great deal more time preparing this paper than I intended to. Like all subjects it gets more fascinating the more you investigate it. I would like to have sent a detailed questionnaire to a larger number of actual propagators and largely as an afterthought, because time was running out, I sent out just a set of questions to all 31 members of the IPPS who describe themselves as propagators.

I put the questions in a way to elicit the most positive response I could without exercising the prejudices that were hardening in my heart. Time does not allow me to elaborate much on their replies because they were incomplete and left too late in the day. Nor were the replies numerous enough to draw too many empirical conclusions.

However for what it's worth 69 per cent of those who replied were negative about their role in the company they worked for and 30 per cent either positive or neutral and careful not to seem too outspoken. What was common to all replies was the enormous enthusiasm for the job itself and the overall feeling that these men and women felt sure they had more to contribute if they were given the chance.

A few of the strongest comments are:

"I think that propagators have been seriously undervalued. It shows in the number that have set up their own nurseries. It shows also in the fact that college-trained managers are two a penny but that propagators are never available . . ."

"A good propagator should keep up with the boss, if not be one step ahead of him. He should be constantly looking for a way to improve. If the boss has a propagator like this, I don't know about asking for a wage rise, the boss should be afraid to lose him . . ."

"I feel from experience that the growing staff on a nursery is undervalued and underpaid when compared to the office staff.

When our own company will not give growing staff the status they deserve it's not surprising that the general public see us as "gardeners". As long as our pay is low we will not attract better people into the industry so we will not improve our efficiency or our image and so we will not be able either to pay higher wages or increase the price we ask for our product."

"For me the attitude of the leaders in our industry to propagators was shown recently when I applied to be a member of the Institute of Horticulture. After 25 years propagating I could only be an associate rather than a full member."

That perhaps puts it into a nutshell.

Before moving on it is relevant to mention that one of the questions asked: "What are the top five motivating elements attached to your job?" The returns produced the following results:

Unanimously, No. 1 was: job satisfaction; No. 2 was: the challenge of rooting; No. 3 was: seeing crop looking good; No. four was equally: improvement of techniques, being a member of the team, having full responsibility, seeing targets achieved and wages. No. 5 was: freedom and ambitions achieved.

It is obvious that something must be done to improve both poor and inadequate training programmes in colleges and at work as they relate to propagation.

It is obvious that there are too few top propagators available and sadly some of these are keeping their secrets to themselves and not preparing the next generation for taking over.

I cannot see the recent trends being reversed and there is nothing for the young person to aim at. Boring propagation may be at times, but well paid is hardly the description. We must appeal to the best young people.

Can we learn from abroad? Well, perhaps. I spent time with André Briant in June and he talked of real differentials on his nursery. Full time experienced nurserymen receive around £8,000 per year and André's heads of department earn double that. I wonder if there is a connection? Good wages, at least with Briant, equal success.

U.K. models are harder to find. There are glimmers of hope but not among the giants. John Newington, whose nursery I admired and took as a model for my own several years ago, tells me his basic wage is now £150 plus bonuses. Quality on the nursery is matched by good sales and an involved and motivated staff. The place has what I call a "good atmosphere" when you visit.

Stewarts' Nurseries in Winchester have established a good young team with all the key workers motivated and enjoying a 40 per cent differential in wages over regular staffers. I was impressed there with David Millais whose comments I did not include because time precluded it, but he spoke so well of his 29 year old boss. He felt motivated and part of a "young team going places." It contrasted sharply with the depression I felt after so many of my interviews.

I would like to see propagators take a pride in their worth and stop being 'deferential workers'. Nurseries are nothing without their propagators, they represent the first link in the chain. But I have an abiding impression of a group of key workers perpetually cap in hand, unable or unwilling to assert themselves.

Propagators, what are you worth? Do your own home work and establish what you contribute to the success of the company you work for. It is no good sitting on the sidelines feeling overlooked and unappreciated.

There are a number of medium sized nurseries developing successfully around the country and run by market-oriented and development-minded men and women. On the whole they come into horticulture from other fields and have brought with them a clear understanding of the job they wanted to do. They know they can't do it alone and they know they must be surrounded by keen, enthusiastic, knowledgeable, and, of consequence, well-paid managers on every level. They are not afraid to pay good wages and not afraid to ask for more than 100 per cent effort but it's my impression those nurseries are getting on, doing an honest job, setting new standards and shaping attitudes for the next generation. I would commend you all to seek this team spirit and recognize the energy and inspiration that can come out of it.

NOT TO THE COLLEGES—ANYONE?

PAUL LABOUS

Merrist Wood Agricultural College, Worplesdon Guildford Surrey GU3 3PE

Recruitment for the National Diploma in Nursery Practices course is declining at Merrist Wood College, and at other county colleges with similar courses. The number of students enrolling for certificate courses in nursery practices is also falling, although not quite so dramatically.

In contrast to this, courses in arboriculture, landscape, and countryside recreation at diploma level are oversubscribed.

The question may well be asked, 'is this a true decline or only a decline in comparison with the 1982 and 1984 peaks?' If the decline is a real one, then why is it that young people fail to see the prospect of a worthwhile career within the nursery business? Do they not realise that someone has to propagate the trees which are to be climbed; the 'soft' landscape material which is to be planted, and the forest species which are to play such an important part of leisure and recreation in the future?

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My thoughts go back to a college industrial liaison day in 1982, when 44 people were invited from the nursery industry and only eight attended, two of whom were past students of Merrist Wood! Could this apathy be one reason for the demise of student numbers?

Perhaps it is because horticulture has a "bad press". Our image within the schools in this country is often a poor one with comments being made such as "horticulture is a basic job with basic pay" or "he or she is not very bright, perhaps horticulture would be the best thing". There again we are lucky if horticulture is even mentioned; it is far more likely to be referred to as "gardening"!

Speaking to a recently qualified ND student from Cannington College, Somerset, yet another question came to light: what is 'nursery practice'? Young people who wish to follow a career in horticulture often think this means amenity or commercial glasshouse production. Where does hardy nursery stock come in? People go to garden centres often oblivious of the mysterious nurseries which have provided all the plants!

Do we pay people in the trade enough? £6,500 per annum after three years at college may compare unfavourably with a similar situation in engineering or computing. The freedom of working out in the open air may not fully compensate for the inability to raise a mortgage.

These are all possible reasons for low student numbers based upon 'feelings'. Perhaps the answer is far more simple and very easily explained by birth rate statistics.

It is clear that the birth rate bulge of the 60's is coming to an end. The prediction for the future is given with falling numbers in the 90's. We in education are being forced more and more into a market situation. Where a market is contracting, positive thinking is paramount. How do we market our product more effectively? Publicity is one way, but does it work? A small amount of research shows a possible link between magazine article publicity for Merrist Wood College and student recruitment figures. But how many young people at school ever pick up trade magazines like *Horticulture Week* or the *Grower*? Probably there are very few. Would it not be more profitable to advertise in gardening magazines such as *Amateur Gardening*?

Finally, where do all the students go? We may design a course to provide people for jobs which we know are there but do they take these posts up? Local authority employment has declined, while garden centres have taken increasing numbers of students. Many of our students now start their own businesses in landscaping, or become journalists, train as company representatives, or join British Telecom.

Probably there is no clear answer as to why people are not filling nursery practices courses but falling numbers may be a result of a combination of factors described in this paper. Colleges are in business to educate and train students. Much work is done in order to try to promote our industry's image but much more could be achieved with the help of the nursery industry itself.

ALLIUMS—MORE THAN JUST ONIONS

DILYS K. DAVIES[1]

The Hardy Plant Society,
Preston, Lancashire

When hunting allium material and slides, for a talk in America in 1982, no one seemed to have any interest in the genus, but suddenly alliums have become respectable, indeed, sought after. While their appeal may be less than that of gentians or primulas, there are plenty of good onions for the average garden.

When collecting plants of a genus the faint-hearted would do well to stick to *Belamcanda, Acorus,* or *Paradisea,* all two-specied genera. Contrariwise, there are around 600 alliums world-wide. Some would say that the only good ones appear on plates—not so.

Most alliums would love life in a Greek meadow, few relish rain-soaked Cumbria. *A. amabile,* (10cm) deep pink, dodging the slug packs, does well; *A. mairei* is a pale pink look-alike. *A. polyastrum* (50cm), purple, and *A. tuberosum* (Chinese chives, 40cm), white, are quite hardy and brighten the September border. *A. macranthum* (40cm), purple, flowers a little earlier.

A. splendens (20cm), lilac, is not spectacular but dries to a pleasant parchment shade. With long exserted stamens, *A. splendens* var. *kurilense* (10cm), is probably correctly named *A. thunbergii.* This small charmer makes a neat pot plant.

A. cyaneum (12cm) flowers in August, and is the toughest and most commonly grown of the bright blue alliums. Easily recognizable by its exserted stamens, it appears under many names. *A. sikkimense* flowers earlier and the stamens are included, as they are in *A. beesianum* (15cms), which flowers in September. This species is difficult to obtain, *A. cyaneum* being most frequently the masquerader under the label.

[1] Secretary, North West Group

of a combination of factors described in this paper. Colleges are in business to educate and train students. Much work is done in order to try to promote our industry's image but much more could be achieved with the help of the nursery industry itself.

ALLIUMS—MORE THAN JUST ONIONS

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When hunting allium material and slides, for a talk in America in 1982, no one seemed to have any interest in the genus, but suddenly alliums have become respectable, indeed, sought after. While their appeal may be less than that of gentians or primulas, there are plenty of good onions for the average garden.

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A. cyathophorum var. *farreri* (17cm) which flowers in July and August is ubiquitous, turning up as *A. farreri, A. tibeticum* or *A.* sp. For all that, it is a good garden plant. All the alliums so far described as enduring rain originate in the Far East.

Most of the American onions are rather harder to grow. The white form of the July-flowering *A. acuminatum* (12cm) is attractive. *A. peninsulare* (12–15cm) keeps its purple/white colouring when dried. The lovely sugar pink *A. unifolium* (20cms) which flowers in June is excellent, dead or alive. The circumpolar *A. cernuum*, recognizable by its crooked neck, has a good deep purple form, *A. cernuum* var. *neomexicanum*.

British onions include *A. ampeloprasum*, which is a two metre tall, July flowering weirdo, and *A. triquetrum* (20cm) which bears white flowers in May.

From Europe come *A. sphaerocephalum*, purple-bronze (45cm) and *A. senescens* var. *glaucum*, lilac (15cm) with spirally twisted leaves, both August flowering. Another globe trotter, *A. carinatum* (*A. pulchellum*?) 'Album' (40cm), has a flowering 'fountain' head in August. Purple and pink variants are available. *A. flavum*, similarly shaped, varies in height from 6cms to 45cm.

The aristocrat of onions is *A. insubricum* (12cm), flowering rose pink in July, usually misnamed *A. narcissiflorum*.

From Greece comes *A. callimischon* var. *haemostictum* (10cm) flowering in September, so fragile, a pot may be the safest place. *A. olympicum*, pink, prostrate, July-flowering, has proved quite hardy in a raised bed in the Lake District.

Allium 'Foresgate' (30 to 45cm) is an attractive June flowering rose-lilac form of chives that has recently appeared in catalogues and is not bad for eating either! Garlic, so formidable to vampires, is rarely seen in flower, finding its way to the kitchen too promptly.

Middle Eastern onions include *A. paniculatum* (8 to 30cm) flowering in July and August in a variety of pastel shades and resembling *A. flavum*. *A. oreophilum* var. *ostrowskianum* appears in many bulb catalogues. *A. paradoxum* var. *normmale* (25cms), white, another aristocrat, resembles lily of the valley and blooms in April.

Even the kitchen onions can have charm. *A. fistulosum* (45cm) white, attracts the bees (How does the honey taste?). The pale yellow of *A. obliquum* (45cm) lightens the July border.

Identifying the Russian onions is a chore. *A. akaka* with broad fleshy leaves belongs in the Alpine house but *A. giganteum* (to 150cm) grows happily outdoors in northern England—or North America.

This small selection should prove that growing alliums is worth a gamble. Most are easily grown from seed. Cutting the seed heads early prevents dissemination, although beware any plant with bulbils in the head.

GLORIOUS MECONOPSIS

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This paper concentrates on meconopsis we have grown on the nursery at Inshriach. Before I plunge into the subject of meconopsis I must describe the conditions in which we grow these magnificent plants.

The climate at Inshriach is as near Himalayan as you will find in Britain, although the rainfall is much less than you would imagine, on average between 750 mm and 900 mm per year. It is the cool climate rather than a heavy rainfall which enables us to grow meconopsis so well.

For simplicity I divide the genus into two groups, the perennial species and the monocarpic species. The word perennial needs no explanation, it simply means that the plants come up year after year producing flowers every year. Monocarpic means that the plant will only flower once, although taking one, two or three or maybe four years to do so. The rosette of leaves which is formed over these years can be very attractive and decorative, especially *Meconopsis nepaulensis*, *M. regia*, *M. paniculata*, and *M. superba*, with their leaves covered with golden hairs of silken texture and some with a silvery sheen.

Geographical range. There are about 40 species, with a single exception confined to south central temperate Asia, from the southern boundary of Kashmir along the Himalayas and intervening ranges to northern Yunnan. The genus also occurs through southern Tibet and the smaller countries of Sikkim, Nepal, and Bhutan through Szechuan to Kansu.

The single exception is *M. cambrica*, which is the type species and which inhabits damp, shady ravines at altitudes of below 2,000 ft in western Europe only, the rest of the species occurs in the alpine woods and scrub meadows and scree slopes above 6,000 ft, several species growing at a height above 17,000 ft, *M. horridula* has been recorded from a height of 19,000 ft. Although the genus covers a large geographical range, the majority of the species are extremely local in distribution.

As I have already indicated, it is the cool climate of the Scottish Highlands which enables us to grow meconopsis so well. It is especially critical that there is adequate moisture during the growing season, but soil should be drier in the winter and a covering of snow is beneficial in protecting the over-wintering rosettes, especially of the monocarpic species. The soil should be on the acid side and should contain plenty of humus such as peat, leaf mould and farmyard manure if available; an addition of grit in the soil enables surface water to drain away, especially in the winter in a high rainfall area.

Propagation. The perennial species can be done by dividing the clumps in the spring when the leaves are about 15cm above the ground. If there is a dry spell after planting it is essential to keep the plants well watered until the new roots start to grow and become established. Although *M. betonicifolia* is a perennial species it is generally raised from seed. It produces masses of seed but it is essential only to save seed from the best colour forms and, of course, it is the only way to raise the monocarpic species. Seed can be sown any time between Christmas and March using any of the seed sowing composts. Pricking out can be done whenever the seedlings are big enough to handle. After growing the plants on they can be planted out in their permanent quarters in the middle of August. If growing the plants in pots for sale they should not be potted in any thing smaller than a 9cm pot, 11cm would be better if the plants are to be kept over the winter for spring sales.

The main disease which attacks meconopsis is downy mildew, some years it is worse than others. It does not kill mature plants but it will kill seedlings very quickly. Benlate (benomyl) or captan give the best control.

Meconopsis grandis. Also known as the "Sikkim grandis", usually referred to as the true *M. grandis* as opposed to *M. grandis* G.S.600 as some authorities maintain that the GS600 form is a natural hybrid, a statement with which I do not agree.

Meconopsis grandis G.S.600. This is one of the great introductions to our gardens, a plant which grows to a height of 1.3m depending on the type of soil, which must contain plenty of humus, and plenty moisture in the spring. It is an extremely hardy plant surviving the lowest temperatures as long as the soil is well drained. It can be propagated by division in the spring.

Meconopsis grandis PSW 6002. Collected by Poulin, Sykes, and Williams in 1952. Since this is a very early flowering species, it is necessary to protect the blooms from frosts. A plant growing to a height of about 60cm, it can be raised from seed or divided in the spring.

Meconopsis grandis 'Slieve Donard'. This plant was raised by William Slinger of Slieve Donard nursery in Newcastle, Northern Ireland; unfortunately this nursery no longer exists. It was a selected seedling from a batch of *M. grandis.* It is one of the finest forms of *M. grandis* grown today. It is a strong grower and can be divided in the spring quite easily. The flower is full and not at all star-shaped.

Meconopsis grandis 'White Form'. This form needs the same conditions as the other *M. grandis* forms, except that the flower stems need staking as they are very susceptible to wind damage.

Meconopsis betonicifolia. The best known of all the blue poppies. Although not quite as tall as *M. grandis* GS 600 it is a wonderful sight. It produces masses of seed, but it is important that seed should be saved from the best colour forms.

Seeds should be sown in early spring and pricked out in the same way as you would prick out primula seedlings. Plants can be planted out in August or September or left to the following spring. If these plants are grown in the south it is wise not to let them flower the first year—pick out the bud and this will encourage new growth from the base of the plant and they are more likely to be perennial.

Meconopsis × *sheldonii.* An excellent hybrid between *M. betonicifolia* and *M. grandis.* It is a robust perennial plant. There are a number of forms of this plant grown today. It divides easily and sometimes produces seed.

Meconopsis Crewdson hybrid. This plant was raised from seed given to us by a Mrs. Crewdson of Kendal. It is almost certainly a form of *M.* × *sheldonii* but has a much fuller, rounder flower. Another good perennial.

Meconopsis quintuplinervia. Known as Farrer's harebell poppy. This species has proved very easy to grow in most places. It owes its introduction to Farrer who sent home seed from Kansu in 1914 and 1915. White forms have been found in the wild but there is no record of them existing in cultivation. It is very perennial and propagates by division in the spring. It does best in good rich soil, deteriorating very quickly if neglected.

Meconopsis punicea. This is very closely related to *M. quintuplinervia* and their distribution areas meet in Eastern Tibet. Introduced by Wilson in 1903. Our plants are raised from seed collected by Ludlow and Sherriff on their last collecting trip just after the World War Two. It is almost certainly monocarpic or at least a very poor perennial; it has been known to flower in two successive years. There have been a number of hybrids raised from crosses between this and *M. quintuplinervia,* one of the best known is *M. cookii.*

Meconopsis delavayi. This is a perennial species disappearing underground in the winter. It was found in Yunnan growing on limestone formations. Introduced by Forrest and flowered in the Royal Botanic Garden in Edinburgh in 1913. It has been in cultivation on and off ever since. We have had it at Inshriach for a number of years and it has flowered most years but alas it is now just hanging on to life.

Meconopsis integrifolia. Farrer's lamp shade poppy is a monocarpic species and is one of the most widespread in the wild, extending from Kansu in the north to southeastern Tibet and most abundant in Yunnan, growing in alpine meadows from 9,000ft to 17,000ft. It flowered in this country for the first time in 1904 from seed collected by Wilson. The winter resting bud is semi-evergreen. Protection with a cloch in the winter is advisable.

Meconopsis simplicifolia 'Bailey's Form'. This is also a monocarpic species, but there is a perennial form which I understand is a poor colour. It is a plant which grows best under dry conditions such as in rhododendron scrub and in the shelter of rocks in its native Nepal. It is found at altitudes from 11,000ft to 17,500ft.

Meconopsis aculeata. A monocarpic species from the western Himalayas and belonging to a group with long fleshy tap roots. *M. horridula* is similar but has darker blue flowers with white stamens; both species have densely spiny leaves and stems and will grow in quite dry conditions.

Meconopsis discigera. Collected by the 1922 Mount Everest expedition and more recently by Len Beer on his Nepal collecting trip in 1975. It is a monocarpic species which varies in colour from rather dull purple-red to shades of blue. Unfortunately our plant did not set any seed.

Meconopsis sherriffii. Collected by Ludlow and Sherriff in Bhutan in 1949 and still has a very tenuous hold in cultivation. We have found this species to be monocarpic in the garden or at best a poor perennial. It does best in semi-shade in not too dry a situation.

TALL-GROWING MONOCARPIC SPECIES

Meconopsis superba. Found originally by a native collector in the Chumbi district of Tibet and again by Ludlow and Sherriff in Western Bhutan. It has a very attractive winter rosette of almost white felty leaves and a spire of many white flowers. It needs to be very well drained in semi-shade.

Meconopsis regia. Very similar to *M. superba* but with a much more golden winter rosette. It can have either yellow or pink flowers and will reach a height of nearly 2m.

Meconopsis paniculata. This is one of the earliest species to be cultivated in this country, it was sent home by Hooker from Sikkim in 1849; it also appears in Nepal. It has a very attractive winter rosette and many yellow flowers on a tall stem.

Meconopsis napaulensis. Probably the best known of all the monocarpic species. It is quite difficult to distinguish it from *M. paniculata* which has a hoary appearance compared with the red-brown rosette or this species. The flowers can vary from yellow, pink, red, and sometimes blue. A very handsome plant.

Meconopsis sarsonsii. A garden hybrid between *M. betonicifolia* and *M. integrifolia*. It is a poor perennial but it comes true from seed although it is not so prolific as its seed parent.

ERYNGIUMS—ORNAMENTAL THISTLES

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The sea hollies are an interesting and wide ranging group of plants. They are natives of Europe, the Americas (particularly South America), North Africa, Asia Minor, and Eastern Europe, and while many are hardy, some species prove tender in the United Kingdom.

The genus has considerable ornamental value which is not widely recognised. *Eryngium alpinum* and *E. tripartitum* are perhaps the commonest, but only the largest garden centres would be likely to stock both.

The merits of the genus lie in the ornamental flowers and foliage. The long lasting thistle-like flowers are usually blue or purple and very striking in appearance. The flowers can provide display from June to October and are well suited to drying for winter display. There may even be some potential in their use as cut flowers. The foliage of most species is attractive and often sharp or thorny. The American species have evergreen, long, narrow leaves often forming a basal rosette, whereas the European species have rounded or lobed leaves and are more fully herbaceous. The plants vary in height from a few centimetres to two metres or more. Their main uses are in herbaceous or mixed borders with a few species suitable for rock gardens.

The failings of eryngiums are not many but need to be recorded. Some of the taller species may require staking and tying if they are to remain attractive throughout the summer. The genus is rather mixed regarding the ornamental value of the plants and even within one species there may be considerable variation. The taxonomy of *Eryngium* species is confused and this does not help in the selection of attractive and commercially valuable plants.

Eryngiums are easy plants to cultivate. The majority of species in cultivation are hardy and will grow best in open, sunny situations. They will thrive even in poor soils, so long as they are well drained, and they are tolerant of a wide pH range. There are no particular pest or disease problems connected with eryngiums and they are trouble free in cultivation.

The propagation of eryngiums is achieved either by raising from seed or from root cuttings. Seed-raised plants are inherently variable and do not have the uniformity and consistent high quality required for horticulture. The initial selection of desirable specimens, which are then treated as clones and only vegetatively propagated, will overcome these difficulties. The selection process

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will be very important and could include a range of desirable characteristics such as dwarfness, hardiness, flower colour, and the length of the flowering period. The subsequent propagation of the selected clones will involve root cuttings unless any attempt is made to use micropropagation.

The Lancashire College of Agriculture and Horticulture holds the national collection of *Eryngium* under the aegis of the National Council for the Conservation of Plants and Gardens. The college has an interesting collection of species, a number of which have potential as garden plants. The following plants are currently being grown outdoors in Lancashire on relatively heavy, silty soil with no particular shelter or protection: *E. ebracteatum; E. yuccifolium; E. tripartitum; E. aquaticum; E. giganteum; E. agavifolium; E. alpinum; E. serra; E. coeruleum; E. tricuspidatum; E. campestre; E. corniculatum; E. palmatum; E. planum* and *E. variifolium*.

A range of other species is held by the college but they are either doubtfully hardy or have proved difficult to propagate. Of the plants named above, the following are most ornamental and could well merit wider distribution in the trade: *E. yuccifolium; E. tripartitum; E. giganteum; E. alpinum; E. tricuspidatum; E. campestre; E. corniculatum; E. palmatum* and *E. variifolium*.

Such a list is obviously subjective and there are certainly a few *Eryngium* species not yet present in the national collection which are worthy of note, such as *E. spinalba* and *E. eburneum*. The recurring difficulties of the classification and nomenclature of the genus make for uncertainty when referring to particular plants and there is no doubt that a number of synonyms have increased the confusion.

ORPINES IN CULTIVATION IN BRITAIN

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INTRODUCTION

Stonecrops (*Sedum* spp.) for the herbaceous border, are accommodating plants that are widely grown, some of which are regular items in nurserymen's catalogues. The ease of production and cultivation may lead to a dismissive attitude among those who grow them but a number of attractive garden plants are to be found in the genus. This account, however, discusses only two species and their cultural descendents, namely *Sedum telephium* and *S. spectabile,* the orpines, both frequently cultivated.

Sedum telephium. This is a species with one of the largest natural distributions of any flowering plant, from Western Europe across temperate Asia to Japan [11], and with an introduced population in the northeast United States and adjacent areas of Canada [2]. Many variants have been named, from nature and from cultivation; in particular, the taxon *Sedum maximum* is used for robust plants frequent in gardens.

In the present botanical climate, in which related species are subsumed into a broadly based central or "natural" species, *Sedum maximum* cannot be maintained as distinct. Certainly the writer's observations on an assortment of variants in cultivation show that the structure of the flowers forms a relatively uniform diagnostic feature throughout.

It is therefore merely a convenience to devise groupings to accommodate the cultivated forms of *Sedum telephium,* based loosely but not absolutely, on the subspecies recognised by Webb in Flora Europaea [11].

Group I: Telephium. Erect habit, leaves elliptical, with a well-marked marginal dentation. Inflorescence a moderately dense corymb with pink or red flowers. This group has the neatest habit of growth when garden planting is considered, compared with those below. *Purpureum* has been used at various taxonomic levels for natural populations with green, non-glaucous alternate leaves; here it is regarded as a synonym of subsp. *telephium.*

Group II: Fabaria. Habit rather lax, leaves oblong or broad elliptical, the margins shallowly toothed, generally alternate, with a dull purple suffusion. Inflorescence dense and globular, or somewhat diffuse, flowers purple, July and August. The British population of *Sedum telephium* is subsp. *fabaria* (4).

Group III: Maximum. In vegetative form related to Group II, but growth is more robust. Leaves oblong or rotund, opposite, suffused purple, sometimes markedly. Inflorescence diffuse, flowers yellowish—or greenish white, August and September.

Individual clones, although assigned to a particular group, may exhibit features of another and more confusingly, cultivar names have been used indiscriminately, and applied to dissimilar selections. The following are believed to be in current cultivation, although not necessarily in commerce:

'Atropurpureum' (Group III). A familiar plant in commerce, growth sparse but shoots intensely purple, much used for floral arrangements.

'Borderi'. A form of subsp. *telephium* with deeply toothed green leaves described from a natural population. Authentic material was supplied to the Dutch field trials, and included in the account of Hensen and Groendijk-Wilders [5]. The illustration in Evans [4] shows a plant with similar foliage, but with a spherical inflorescence, that is, it combines features of Groups I and II. Masters, Praeger and Chittendon [3, 7, 8] nominate a grey-leaved plant with red stems from Group I, while another Group I selection has bronze shoots with red flowers. The total of clones which may be labelled 'Borderi' is brought to five with a Group II plant very close to naturally occurring subsp. *fabaria*.

'Foeminum'. The plant supplied from continental nurseries as *Sedum telephium* is a male-sterile clone of *S. purpureum* (sic), with minute petals, the rosy-pink flower colour supplied by the carpels. Praeger describes but does not name this [8]. Widely grown in gardens but rarely labelled, then perhaps as 'Borderi'.

'Maximum'. The plant seen as the type of *Sedum maximum,* with rather chlorotic foliage and yellowish flowers is hardly worth growing. It may also be suffixed 'Aureum' or named *Sedum caucasicum.*

'Munstead Dark Red'. The clone in the trade is intermediate between Groups II and III, with purple stems and dull purplish-green leaves. A quite dissimilar plant described by Evans (4), and grown at Kew Gardens, is a purple-leaved pink-flowered form in Group III.

'Roseo-Variegatum'. A plant found by the writer in a private garden was inconstant. Another source proved to be untrue, Group II.

There are further clones: 'Arthur Branch'; 'Cloral Cluster'; 'Redcap' and 'Sheila Macqueen' which may be available in commerce or seen in gardens. A full listing by Masters (7) must include cultivars never seen in Britain.

Sedum telephium has a long history of cultivation with a substantial number of medicinal applications as recorded by Thomas Culpeper (seventeenth century), mostly used externally, as the sap has a cooling effect on sores and burns (1). A rather different corpus of folklore concerns the magical effects of charming away evil, or predicting marriage prospects [9]. Rarely are its culinary uses recommended today; for salading or for flavouring soups and stews [6].

As garden plants, the complex of *Sedum telephium* is now of minimal importance except for the few cultivars of value for floral arrangements. However, as so many clones have survived, despite their dubious identities, it suggests that their amenity value should be given prominence. For dry or otherwise excessively drained sites, whether sun or shade, this herbaceous stonecrop has yet to be exploited for its quality of persistence, and its endurance in difficult circumstances.

Sedum spectabile. One of the most familiar of border plants, the merits of *Sedum spectabile* were recognised soon after its introduction (from cultivation in Japan) by Shirley Hibberd, who gave fulsome tribute for its tolerance of sun or shade, and for planting in dry or moist places [10]. An attractive flowering plant for late summer and autumn, the readiness to force has provided florists with an easy crop with an extended season [7, 8]. Neither Masters nor Shirley Hibberd noted any variants [7, 10], but the twentieth century has seen a continuing stream of introductions, some of which are enumerated below. The account of Hensen and Groendijk-Wilders provides names and brief descriptions of other cultivars grown in Europe [5].

Cultivars:

'Brilliant'. The most widely listed of the deeper coloured garden selections. 'Atropurpureum', 'Atrorubrum' and 'Atrosanguineum' are attendant synonyms or similar selections.

'Carmen'. A later introduction still available.

'Gwendoline Parr'. Flowers parti-coloured pink, white and green.

'Iceberg'. Perhaps identical with 'Gwendoline Parr', flowers coloured with green and white.

'Indian Chief'.

'Meteor'.

'September Ruby'. The deepest coloured selection, rated 'excellent' in the Dutch field trials [5]; introduced to, but not established in, Britain.

Other Cultivars of Hybrids between Species. Discounting the intermediate variants in *Sedum telephium* resulting from genetic exchange between the subspecies or their sibling groups, the few interspecific hybrids provide the most widely planted orpines today.

S. × *erythrostictum* syn. *S.* × *alboroseum*, an evident descendent of *S. spectabile*, is always offered in the yellow blotched foliage form 'Variegatum'.

'Autumn Joy'. (S. spectabile × S. telephium). The most commonly grown taxon. 'Ruby Glow' (*S. cauticola* × *S. telephium*). The writer is uncertain that the given parentage is correct.

'Sunset Cloud' (or 'Evening Glow'). A weak constitution has limited the distribution of this bronzy-green plant.

'Vera Jameson'. Well established in commerce, the origin has been suggested as *Sedum telephium* (Group III) 'Atropurpureum' crossed with *S.* 'Ruby Glow'.

PROPAGATION

Seed. The species sometimes self-sows in gardens, but seed production is not used in commerce. However, it is possible to collect from *Sedum spectabile* and several variants in *S. telephium* about 25 days after pollination. Under open storage, the longevity of seed is about a year. From a spring sowing, the seedlings reach flowering age in 16 to 18 weeks from germination. Juvenile plants have markedly petiolate leaves, given them a quite distinct appearance.

Division. Lifting and dividing large clumps is a necessary cultural operation for border plants every few years, or a routine means of multiplication in the nursery, possible at anytime but easier during dormancy than during active growth.

Early spring cuttings. Shoots, a few weeks into active growth, around 10 cm. in length, are taken with a "plug" of rootstock, a method identical with that used for lupine or delphiniums.

Early summer cuttings. When the shoots are somewhat firmer, shoot tips may be used.

Late summer cuttings. Shoots in flower may be used while the foliage remains in good condition, that is, well into September. The inflorescence is removed, and the shoot cut into two or three portions.

Whatever propagation facilities are available will successfully root cuttings—cold-frame, open glasshouse bench, or mist unit.

Root cuttings. The writer has demonstrated that *Sedum* 'Autumn Joy' will successfully regenerate from root pieces, but has had no positive response with any clone of *Sedum telephium* tested.

Foliar embryos. Similarly, the writer has shown that sound leaves, cleanly detached from the parent plant, will sprout from the base in both *Sedum spectabile* and *S.* 'Ruby Glow'. While of academic interest at present, it is a method for consideration when rapid multiplication is required.

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EXPLORATION FOR AND INTRODUCTION OF MAPLES INTO CULTIVATION

J. G. S. HARRIS (F.L.S.)

Mallet Court Nursery,
Curry Mallet, Taunton, Somerset

Although the British Isles supports only a limited native flora it is ideally suited to growing the many plants that have been introduced from abroad.

Acer campestre is the only native maple, having come into the country from Europe after the Ice Age across the land bridge between Dover and Calais before the sea level rose.

The next maple to arrive was the sycamore, *Acer pseudoplatanus*, which probably arrived in Scotland in about 1480, where it was known as the plane tree. The first mention of it in literature is by Turner in his Herbal of 1551. Later, Sir T. D. Lauder writes "It is a favourite Scotch tree having been much planted about old aristocratic residences in Scotland and if the doubt of it being a native of Britain is true . . . then it is probably the long intimacy which has subsisted between France and Scotland that may be the cause of it being so prevalent in the latter country".

In Scotland, the sycamore was also known as the dool, or grief tree, because powerful barons used the sycamore for hanging their enemies.

The introduction of plants from foreign lands received much encouragement in the 17th and 18th centuries. Botanic gardens were established in many cities and it was these and their sup-

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The introduction of plants from foreign lands received much encouragement in the 17th and 18th centuries. Botanic gardens were established in many cities and it was these and their supporters who looked for new plants from abroad.

In 1700 a Frenchman, Joseph Pitton deTournefort, who held the chair of Botany at the Jardin du Roi in Paris, was commissioned to explore Greece, Asia Minor, and Armenia. He established a plant classification system first explained in his *Element de Botanique* in 1694 and later in more detail in *Institutiones Rei Herbariae* in 1700 where is found the first description of *Acer*, establishing Tournefort as the father of the genus. A specimen of *Acer orientale* [syn. *A. sempervirens*] which is native to the eastern Mediterranean is reputed to have been planted in the Jardin by Tournefort in 1725.

A few years earlier, Andrew Balfour and Robert Sibbald had established a garden in Edinburgh which became The Royal Botanic Garden. James Sutherland was appointed to the "Care of their Garden", and introduced Acer platanoides into Scotland from southern Europe in 1683.

Several maples were introduced to the Chelsea Physic Garden, by its celebrated Superintendent Phillip Miller who took over the job from his father in 1722. In 1738 he brought in the Montpellier maple, A. monspessulanum; in 1759 A. orientale; and in 1759 the Tartar maple, *A. tataricum*, which is native to southeast Europe and Asia Minor. The Calmucks collect the seeds of *A. tataricum*, stripping off their wings and boiling the remainder in water to use as a food mixed with milk and butter.

In 1768 Miller described 10 species of maple with useful information on their culture. He wrote: "Most of the sorts of maples which come from America are very impatient of heat while young. Their seed should be sown in a sheltered situation. Of plants exposed to full sun but one day when they first appear, few will survive, especially the sugar maple. The seed should be sown with a good depth of soil covering them to protect them from mice".

The traffic in trees and plants from America to Europe had begun a century earlier after the establishment of the colonies.

Amongst the plants introduced by John Tradescant the younger is the red maple, A. rubrum in 1656. In 1741, Miller writes "The Virginian flowering maple, *A. rubrum*, was raised from seeds which were brought from Virginia many years since by Mr. John Tradescant in his garden at South Lambeth, Nr. Vauxhall, and since is in the garden of the Bishop of London at Fulham where it has flowered for several years and produced ripe seed from which several plants have been raised". This Bishop of London was Henry Compton the Head of the Church for the American Colonies. He was a most successful importer of American plants and his garden at Fulham Palace was greatly renowned.

One of the missionaries whom Dr. Compton sent out to America was John Bannister who arrived in Virginia in 1678 and it is probably he who collected seed of *A. negundo*, the ash leaf maple. It was not originally recognised as a maple and was named *Negundo fraxinifolium*.

In 1728, Sir Charles Wager introduced *A. saccharinum* which was originally known as *A. eriocarpum* or commonly as Wager's maple. It flourished in Sir Charles's garden at Parsons Green; Fulham and Miller, speaking of this maple, says "This, the gardeners distinguish by the title of Sir Charles Wager's maple but as there is no difference in the flowers, seeds or leaves from *A. rubrum* so they must be deemed but one species as there are only accidental varieties arising from seed".

William Aiton in his *Hortus Kewensis* (1789) records that the sugar maple, *A. saccharum*, was introduced by Peter Collinson, a Quaker linen draper from London, in 1735; and that *Acer pensylvanicum* was introduced in 1755 by Messrs. Kennedy and Lee of the Vineyard Nurseries, Hammersmith, London.

The 19th century opened with the discovery of a land route across the United States of America to its western shores. In 1792, Dr. Archibald Menzies sailed on the Discovery with Captain Vancouver and on May 2 in the following year he obtained the first sighting of the big leaf maple, *A. macrophyllum*, on Protection Island at the northeastern tip of the Olympic Peninsula.

In 1804 the United States government sponsored an expedition to find a practical route to the Pacific, appointing Captain Meriwether Lewis and Captain William Clark to lead it. The expedition reached the Pacific on 7th October 1804. An extensive collection of plants and specimens made on the outward journey were lost at the Great Falls but a smaller collection on the homeward journey survived. Everything was new to science and among the specimens were *A. circinatum* and *A. macrophyllum*.

In 1823 the Horticultural Society and later the Royal Horticultural Society employed David Douglas, a Scotsman, sending him first to the eastern United States and then the following year to the western United States. In 1826 he travelled by the Columbia river and collected and sent back to London seed of *A. macrophyllum* and *A. circinatum*. Douglas wrote in his journal "*Acer macrophyllum* of Pursh [is] one of the largest and most beautiful trees on the Columbia river, . . . correctly noted by Pursh to have the largest foliage of any".

A year earlier when he was collecting for Professor J. D. Hooker, Douglas discovered a form of the rocky mountain maple in the Blue Mountains which Hooker names after him, *A. glabrum* ssp. *douglasii*. It is a maple with attractive purple stems. At first Douglas sent only leaf specimens, but later seeds.

The beginning of the 19th Century saw the start of botanical exploration in India. In 1817, the Danish surgeon Nathaniel Wallich was appointed Superintendent of the Calcutta Botanic Garden. Among his collectors was Kamroop who discovered *A. acuminatum*. Others included John Forbes Royal who collected *A. villosum* at Choo Mountain, and Dr. George Goven who discovered

A. pectinatum at Sirimore.

The great floral treasurers of China and other countries in the Far East were now about to be discovered. In 1775 Carl Thunberg arrived in Japan. He was restricted to an island in Nagasaki Harbour where he was able to collect a few plant specimens from which he made the first description of *A. palmatum* and *A. japonicum*.

In 1826, Dr. Phillip Franz von Siebold, a German physician, arrived in Japan. In 1845, Siebold published the first description of many maples indigenous to Japan including *A. carpinifolium, A. crataegifolium, A. distylum, A. micranthum, A. rufinerve,* and *Acer cissitolium* [syn. *Negundo cissifolium*].

In 1853 a treaty with the United States of America led to the opening of Japanese ports, and botanists came flocking in.

In 1853 Carl Maximowicz explored the virgin forests of the Amur river, where he found *A. barbinerve* and *A. mandshuricum*. Maximowicz then went on to Japan spending four years collecting plants. In the province of Senaro he discovered *A. mono* subsp. *mono, A. capillipes, A. japonicum* and *A. nikoense*. His attendant, Sukawa Tschonoskii, was appointed to collect, and found *A. argutum* and *A. caudatum* subsp. *ukurunduense*. After Maximowicz had returned to St. Petersburg Tschonoskii continued to collect for him and found the maple which now bears his name.

In 1879, Charles Maries, working for James Veitch & Son, made a large collection of trees and shrubs, including many maples, near Sapporo. *A. crataegifolium, A. carpinifolium* and *A. rufinerve* were sent back to Veitch.

Travel was also restricted in China. In 1832, the Horticultural Society sent John Reeves, who collected *A. palmatum*. Dr. Alexander von Bunge arrived with an ecclesiastical mission from Russia and near Peking collected *A. truncatum*.

No further exploration took place in China until after the end of the Opium War. In 1862 Armand David arrived in Peking. He made three journeys into the hinterland with a stoic disregard of local insurrections, and his own constitution.

In 1868, David discovered *A. davidii* in Mupin which was introduced by Maries. The Golden Age of plant hunting was now about to dawn. In 1888, a remarkable Italian missionary, Father Giuseppe Giraldi, arrived in Shaanxi. On Mount Thae-pi-san he discovered the maple which Pax named after him, *A. giraldii*. Forrest also collected it between 1913 and 1915 and sent back seed to his employer, J. C. Williams of Caerhaes Castle. Giraldi also discovered in Shaanxi *A. grosseri*, which Joseph Hers introduced into cultivation in 1919.

In 1881, an Irishman, Augstine Henry, arrived in China, to work for the Chinese Maritime Customs at Ichang. He took an interest in the flora and began corresponding with Dr. William Thistleton-Dyer at Kew Gardens. In the high mountains of Hubei

Henry collected 10 new maples, including A. erianthum, A. henryi, and *A. sinense*.

Before leaving China in 1900, Henry had written to Professor Charles Sprague Sargent, then director of Harvard's Arnold Arboretum, suggesting that a younger man take over. Ernest Henry Wilson was appointed, and he arrived in China in 1899 where, on and off, he was to spend the next 15 years or so. He describes a day's march made through Hubei in 1910 "We traversed an old wood especially rich in species of maple . . . I gathered *Primula violodora* . . . *Acer griseum*, and a pink-flowered staphylea . . .". A day or so later Wilson describes walking through some fine woods "Maples in variety are very common, one large tree of *A. griseum* with chestnut red bark, its foliage looking like the river birch was the gem of all". In 1901, Wilson sent seed of this maple back to his employer.

In the limestone mountains of Hubei near Hsingshan Wilson collected 11 species of maple including A. amplum, A. fulvescens, *A. maximowiczii* and others. In all, he collected some 30 species of maple, including *Dipteronia sinense*.

After Wilson came George Forrest who arrived in China in 1904. His main collecting area was in the Likiang range of mountains, where he collected a fine maple which Diels named after him in 1912. He collected many maples in the Lutien Valley, including *A. oliverianum*, *A. stachyophyllum* [syn. *A. tetramerum*], and *A. giraldii*. In all, he collected over 25 species.

These three—Henry, Wilson, and Forrest—were the giants of plant collectors in China but there were many other colourful characters. These include a Russian, Potanin, the first to take his wife on expeditions and who discovered *A. multiserratum;* Antwerp E. Pratt who collected *A. laxiflorum;* Frank Kingdon-Ward who collected *A. wardii* and others; Heinrich Freiherr von Handel-Mazzetti who collected *A. taronense* and Joseph Rock an Austrian who became Professor of Botany in Chinese at the University of Hawaii and who collected *A. pentaphyllum* in the Valley of the Yalung River in July, 1929.

Lying to the south of China is the island of Formosa where there are half a dozen or so indigenous maples. These were collected by Japanese although several Europeans visited the island for example, Wilson in 1913 who collected specimens of many of the Taiwanese maples. K. Yashiroda collected seed of *A. morrisonense* in 1932 which he sent to Trewithen in Cornwall and in 1970 Professor Huang of Taipei University collected seed of this maple for the author on Mount Morrison, and later collected and sent seed of *A. serrulatum*, *A. kawakamii* and *A. albo-purpurescens*.

Lying between China and Japan is Korea, whose flora has been much neglected. It has a rich flora which has never been overrun by glaciation. The first European collector there was Richard Oldham, who arrived in 1877. He was followed by Vladimir Leontievich

Komarov from Russia who in 1901 discovered *A. triflorum*. This maple was ultimately introduced into cultivation in England in 1923. Other famous visitors included Père Urbain Faurie, who was one of the most remarkable but the least known, from the horticultural standpoint, of the French missionaries, and Wilson who arrived in 1917 and travelled there with Takenoshin Nakai. In 1982, I was fortunate to visit Korea and Ullung-do and to collect two endemic maples—*A. okamotoanum* and *A. takesimense*.

While maples are still to be discovered in the older countries, especially China, the descendants of the settlers who set out from Europe to find new lands and settle there now share with the descendants of those who stayed in the exploration and exchange of seeds and plants of known species and new forms. The maple has established itself as a plant of great ornamental beauty with increasing popularity.

MALUS SPECIES AND CULTIVARS

JACK H. SWAN[1]

Jodrell Bank Arboretum
Cheshire

The Arboretum, of approximately 40 acres, was established in 1972 at Jodrell Bank on the eastern edge of the Chesire Plain. The soil is derived from a heavy boulder clay, becoming progressively lighter towards the eastern section of the Arboretum. The consequent poor drainage causes some problems in the establishment of trees with the planting sites more or less acting as sumps in the late winter months. However, this is compensated for during dry springs and summer drought when very few losses occur. The lighter eastern section has few problems and there is better establishment and growth. Early establishment of shelter planting on the eastern side of the arboretum has helped to alleviate any exposure problems and there is little wind damage. The beneficial effects of this shelter are readily seen when the cold easterlies take place in January to March and damage occurs on the more open sections of the arboretum.

Winter temperatures regularly go down to −12°C and in most springs we have a series of late frosts, which have a considerable effect on the fruiting of many of the malus in exposed positions. *Malus* 'Red Sentinel' is usually a very reliable fruiting crab, yet this year (1987) it has failed to do so due to frost. The beneficial effect of the shelter planting is very obvious this year, with good fruiting in well sheltered positions.

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When the Arboretum was set up in 1972 it was decided that a collection of malus would be established. Following the establishment of the National Council for the Conservation of Plants and Gardens we offered the site for national collections and the malus were accepted. At present we have 73 species and cultivars planted out with a further 36 being grown on for future plantings. Most of the original plants were bought in from various sources, while those to be planted were provided by Long Ashton, and others propagated on behalf of the other national collection of malus at Hyde Hall in Essex.

The *Malus* × *purpurea* group and other purple-leaved forms are naturally slower growing but even after 10 years or more their progress has been slow. With odd exceptions they are still disappointing trees. *Malus* 'Profusion', with its wine red flowers, is a notable exception in this group, whilst 'Chilko', 'Simcoe', 'Hopa' and 'Red Tip' are making some headway.

From the wide range of species and cultivars I have selected a number which show considerable interest. Some are, of course, well known, others less so. *Malus floribunda* with crimson buds opening to pale blush flowers is a very reliable floriferous small tree. *Malus* 'Wintergold' has pink-budded white flowers over two to three weeks, followed by clear yellow fruits carried well into winter. Malus 'Golden Gem', also with pink-budded white flowers, is very reliable, followed by yellow fruits, smaller than the better known *Malus* 'Golden Hornet'. *Malus* 'Crittenden' has pale pink flowers followed by attractive bright scarlet fruits. *Malus* 'Red Sentinel' has proved to be a very reliable flowering and fruiting tree with the deep red fruits remaining until well after Christmas.

Malus 'Cashmere' and *Malus* 'Lady Northcliffe' both flower and fruit consistently. *Malus* 'Dartmouth', with white flowers followed by red and yellow fruits, is reliable, whilst the more common *Malus* 'John Downie' is rather an inconsistent fruiter in the arboretum. *Malus* 'Hillieri' with its bright pink flowers is very attractive. *Malus baccata* and *Malus baccata* var. *mandshurica* are good flowering and fruiting trees. To add a wide range of colour to the plantings we have *Malus* 'Katherine', semi-double pink flowers, and *Malus* × *magdeburgensis*, deep red buds opening to purplish pink.

I am always looking for trees that could be recommended for the smaller garden, for different shapes, and trees to give extra character. Amongst the small malus, *Malus sargentii* is excellent with its pure white flowers followed by its small red fruits which are quickly eaten by thrushes. *Malus sieboldii* shows promise with its semi-weeping habit and profuse small white flowers. A new cultivar, *Malus* 'Evereste', showed early promise as a small tree with large apple blossoms and good-sized fruits, but subsequent growth could prove it too large for a small garden. *Malus* 'Red Jade' with its white and pink flowers is a fine, small, weeping tree. The distinctive *Malus trilobata*, with its erect growth is good for restricted areas with its attractive maple-like leaves and good autumn colour. *Malus toringoides* and *Malus transitoria* are also attractive with their maple-like leaf shape. They also produce fine autumn colour, the latter having particularly fine yellow gold tints.

When more space is available, *Malus hupehensis* with profuse small white flowers is very good, as is the better known *Malus* 'Van Eseltine' with its scarlet buds opening to pink flowers. *Malus kansuensis* has good elongated red and yellow fruits, whilst the erect growing *Malus prattii* and *Malus yunnanensis* have very good autumn colour. *Malus tschonoskii* is probably the best known for autumn colour and is a strong growing tree.

Amongst new plantings to be made there are several cultivars of potential interest. *Malus* 'Dolgo', large single white flowers and 'Basketong', 'Purple Wave' and 'Roberts' Crab' from the *Malus* × *purpurea* group with red leaves and reddish-pink flowers show great promise.

HOSTAS

DIANA GRENFELL[1]

Apple Court, Hordle Lane
Lymington, Hampshire

The first hostas to arrive in Britain were *H. plantaginea* and *H. ventricosa* imported from China in 1789 and 1790 and still extensively grown today. *H. plantaginea*, the old August lily, is more at home as a tub or pot plant in gardens in the South of France, but flowers well in southern Britain if grown by a sheltered south-facing wall. Its hybrids 'Royal Standard' and 'Honeybells' were raised in America in the 1950's; with their *H. sieboldii* parentage, they increase rapidly, making ideal ground cover and landscape plants, with fragrant flowers. Kevin Vaughn, and Mark Zilis, two American plant geneticists, have used them as parents to produce hostas with streaked and variegated leaves and very fragrant flowers. Two recent cultivars are 'Sugar and Cream' and 'Sweet Standard', but 'Summer Fragrance' is the first to have scented purple flowers and variegated margined leaves.

The von Siebold introductions to Holland and Belgium led to nomenclatural confusion when the hostas were later introduced to Britain, with botanists hastening to honour von Siebold. Of these, *H. sieboldiana*, which must surely be the archetypal hosta, is often

[1] British Hosta and Hemerocallis Society

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called *H. sieboldii* although they are quite different. *H. sieboldiana,* large and glaucous-leafed, has many variants of which we usually grow var. *elegans,* larger, more rounded and bluer than the type, and 'Mira', a giant form with pointed leaves.

The variegated form of var. *elegans,* 'Frances Williams', named at Oxford Botanic Gardens, is quite the most popular hosta grown today. In common with most hostas it takes at least 4 years to develop its true character: deeply puckered leaves and wide, creamy-yellow margins. 'Golden Circles' is a sport of similar character. Both occasionally produce crowns bearing all-gold leaves. If these crowns are isolated and kept growing well, they may be stabilised, in which case they must be called the umbrella name 'Golden Sunburst'. An exciting new break is a plant named 'George Smith' which is, in effect, a reversed 'Frances Williams' with a pale centre and blue margins. American tissue culture laboratories have now produced a 'Frances Williams' type, but with a white edge, 'Northern Halo'. An even newer sport from this is 'Northern Mist', not yet available.

One problem with these micro-propagated hostas is that there can be 10,000 on the market within two years of the first appearance of a new break, but we actually need to grow them in gardens for 5 years to find out what they do.

Hosta tokudama is a slow-growing species, probably related to *sieboldiana.* It is considerably smaller, has deeper blue, cupped leaves which, unfortunately, collect debris from overhead trees and so on. Sadly, it is too slow-growing to be anything other than a collectors' item, as are its beautiful forms, the cloudy-yellow streaked 'Aureo Nebulosa' and yellow-edged 'Flavo Circinalis'. 'Aureo Nebulosa' is now much used as a parent in the U.S., one of the latest offspring being 'Fleeta Brownell Woodruff', a winner at this summer's Annual Convention.

Eric Smith's hybrid from *H. tokudama,* 'Buckshaw Blue', has also won many awards, although it is not a vigorous plant in Britain. However, the hotter summers in the U.S. encourage it to perform more successfully. It is a pity that so many poor seedlings masquerade under its name.

Hypoleuca urajiro, the white-backed hosta, is an equally desirable rare species. If well nourished it soon becomes clump-forming, discarding its natural habit of producing one or two very large leaves. *Hypoleuca*'s pale green leaves have a certain amount of pruinosity and like other hostas with a bluish cast to their leaves, it does sometimes become virused.

Hosta venusta, is the best-known dwarf species we grow, and is particularly suitable as a rock garden plant. It flowers prolifically, increases rapidly but its stoloniferous roots can easily be teased apart to make other divisions.

H. kikutii, little known in Britain in either its type or forms until

Sandra Bond's Gold Medal Hosta Exhibit at a R.H.S. Westminster Show this summer, is a plant for the connoisseur or collector. Its ribbed, gracefully spreading leaves will be appreciated by those who can spot a good plant. A kind American collector is sending us plants of all the forms found in the wild, and an American nurseryman is now raising new hybrids. Our plant has pale mauve, flaring trumpet-shaped flowers of a distinguished quality.

H. fluctuans is now becoming known because of its attractive variegated form, and is one of the most desirable newcomers to Britain.

Akin to *H. sieboldiana* is *H. elata*. An unusual hybrid from *H. elata* seed, 'County Park', resembles a cos lettuce in shape. Its rugose leaves are packed tightly together thus tending to rot at the base, interesting, but not a good garden plant, in spite of its charming white flowers.

The slow-growing form of *H. montana*, 'Aurea marginata', is one of the most dramatic garden plants. This hosta can also throw gold-leafed sports and American tissue culture laboratories are using it to produce a medio-variegated form 'On Stage' and a form with cream edges, 'Shogun', both untried in Britain.

Another large species of bluish cast is *H. nigrescens*, little-known or grown in Britain, though popular in America. It is thought to be a parent of 'Krossa Regal', a large, vase-shaped hybrid with undulating flower spikes reaching 1.2 m. It was recently awarded a Certificate of Preliminary Commendation at a Royal Horticulture Society (RHS) Show. Its supposed gold form is not, in reality, a true gold colour, merely pale green unless the sun is exceptionally strong—and it is not really like 'Krossa Regal' at all. However, it does have wonderful ashen-mauve flowers, borne in profusion, on attractive tall pale grey scapes.

H. rupifraga too, ought to be better known. It grows virtually unnoticed in one or two botanic gardens yet it makes dome-shaped clumps of heavy-textured, shiny, heart-shaped leaves small enough to be accommodated in most gardens. Its congested racemes of deep purple flowers won an award at an RHS show.

H. undulata has never been seen in the wild. It was brought to Europe with von Siebold's first batch of hostas in 1829. Von Siebold's Japanese collectors saw it growing in a Nagasaki garden. It is only designated a species for convenience. It is unstable in all its forms. It has particularly well-marked flower bracts which actually look like flowers. Its changeability often puzzles growers since the second crop of leaves carry virtually no variegation at all, merely indistinct streaking. Mature plants often sport green shoots, the green plant then becoming *H. undulata* 'Erromena'. 'Thomas Hogg' in Britain is thought to be the white margined form. However, many unidentified white-edged hostas are called 'Thomas Hogg' without any justification at all. The central area of white in *H. undulata* ranges from virtually the whole leaf as in *H. undulata* var. *undulata*, to 'Medio-variegata' which is about half and half to 'Univittata' which is recognised by its half inch wide white central band. *H. undulata* is grown as an edging plant around houses and along borders in many parts of America.

Species first found in the wild in their variegated forms must carry the species epithet. The most widely grown of these is *H. sieboldii* or *H. albomarginata* as it used, wrongly, to be called. Its green form has trumpet-shaped white flowers, thought to be even larger in the hybrid 'Weihenstephan'. The white-edged seedling 'Louisa' was the first hosta raised with white flowers and white margins. Unfortunately it is not particularly vigorous in Britain.

Large plantings of *H. decorata* in the U.S. were the first indication that it is a very good hosta indeed, making a good looking ground cover but difficult to grow in Britain. It is unmistakeable for its dark green leaves and hard white margins.

More misidentification occurs over *H. crispula* than with almost any other hosta. In *H. crispula* the whole leaf undulates—not just the margin. It has a certain poise which sets it apart from all other hostas, and there are literally hundreds, of similar type. *H. crispula* flowers in mid-June, earlier than any other hosta, which is the certain means of correct identification. It is most often mixed up with 'Thomas Hogg' and *H. fortunei* 'Marginato Alba', and to confuse things when these are grown in moist soil in the shade, they often produce leaves almost as good as those of *H. crispula*.

H. fortunei is an umbrella name for a group of similar leaved garden forms—a species of convenience. Most of the botanical variants are infertile but produce good hybrids through bud-sports. Glaucous 'Hyacinthina', easily recognised by its fine, white pencilled margin, has a variegated form which has produced sports which are even better. 'Phyllis Campbell' has dark green veining overlaying the cream leaf centre and 'Julie Morss', which from its appearance must have *H. sieboldiana* in its genes, is outstanding among the newer British-raised hostas, having good shape, poise, and leaf texture, as well as well-marked variegation. Collectors think that if it were quicker to increase it might rival the Chelsea hosta, *H. fortunei* 'Albopicta'. 'Elizabeth Campbell', no known relation to 'Phyllis', is an improved form of 'Albopicta' which has the advantage of retaining the variegation for longer into the summer. 'Gold Standard' 's leaves unfurl a pale chartreuse green which slowly turns gold, making an excellent contrast to its spinach-green margin. A strange sport from *H. fortunei* 'Aurea', 'Nancy Lindsay' is speckled green and gold, similar to the little known *H. crispula* 'Lutescens'.

It was not until the RHS mounted an exhibit at Chelsea in 1968 depicting the wide range of species found in the wild that gardeners and nurserymen really became interested in wild hostas like the

Japanese *H. longipes*. The last 20 years has seen cooperation with Japanese collectors and botanists. One such collector was Eric Smith. He made his name crossing *H. sieboldiana* var. *elegans* with late-flowering *H. tardiflora*, resulting in the Tardiana group of small, glaucous-leafed hybrids. The best of these is 'Halcyon' which was awarded an AM in 1973 after trials at Wisley. Eleven others were also named but now the British Hosta and Hemerocallis Society, working with Wisley, the National Reference Collection holders, is naming all the numbered Tardiana group hybrids which can be correctly identified. The National Collections here and in USA (under the American Hosta Society) will then carry standard specimens, in dried form as well as growing plants. These National Collections will enable nurserymen to bring their own plants for comparison and in time we hope this will bring some degree of uniformity to the genus.

Hostas are currently the best-selling perennial in the USA, and fortunes are being put into tissue culture work. This creates problems as well as exciting new plants. When we import tiny scraps of immature plants, we have no idea of how they will eventually look in our gardens. 'Resonance' is one such. It looks ideally suited to a rock bank, but see it in maturity in an American shaded border and you would not believe that it is the same plant.

It is a temptation to raise too many hostas and there are obviously some which do not make good garden plants. 'Reversed' looks so desirable in a catalogue, but Americn growers find that it melts out even in their deepest shade. We are trying it here but would not recommend it yet. Less flamboyant, but more obviously a good new hybrid for small gardens is 'Allan P. McConnell' which seems to withstand some sun, yet with its variegated margin looks fresh and cool.

By contrast, 'Green Acres', 'King Michael' and rich gold-leafed 'Sum and Substance' dwarf the largest plantings of *H. sieboldiana* and *H. montana* and are being bred to resist slug damage. 'Sum and Substance' lives up to its name and has leaves the size of a large dinner plate.

Little gold variegated 'Golden Tiara' should be in every British perennial catalogue, being neat, clump-forming and ideal for the small garden. Tissue culture has thrown up an all-gold form, 'Golden Scepter' and another with a gold centre and white margin. Other small golds worth growing are 'Lemon Lime' and 'Golden Prayers'. My preference would be for 'August Moon', of *H. nigrescens* stock which, although a clear, soft yellow, has a slightly bluish cast or bloom. It increases rapidly, has good flowers and is a tissue culture lab's dream, since while reproducing very accurately, it does sometimes throw up marvellous sports like 'Lunar Eclipse' with white margins and now 'Mayan Moon', gold with a dark green narrow, irregular margin, which I covet more than any other hosta.

Before the advent of tissue culture, a number of new breaks were achieved by using various techniques such as x-rays. This method produced 'Flamboyant', which presumably has damaged genes. The juvenile plant exhibits three or four colours in every leaf. As the plant matures, three or four years later, these multiple variations disappear and the leaves end up with merely a wide cream margin. Not unpleasing but not the original 'Flamboyant'. The mature form has been given the new name of 'Shade Fanfare'. This raises problems with the Trade Descriptions Act if the plant is not carefully described at the point of sale.

It may be tempting to buy in all these new cultivars as soon as they appear, but do not let us forget that they are bred primarily for heavily shaded American gardens where the climate and more particularly the intensity of sunlight, is quite different from our own.

Hostas are wonderful foliage plants and in the end it is their shape, poise, and bearing rather than a complex variegation which singles them out as aristocrats.

PRIMULAS

PETER FOLEY

Holden Clough Nursery, Holden,
Bolton By Bowland, Clitheroe, Lancashire

Introduction to the genus. Primulas are a vast genus, covering the whole of the northern hemisphere. We grow somewhere in the region of 300 different species, cultivars and hybrids, an indication of how freely primulas hybridise. If you get primulas of the same section, such as the candelabra section, together you end up with hybrids. At the nursery we plant the different cultivars well away from each other to prevent crossing and untrues. Primuls are so notorious, that if you get seed from seed exchanges you should actually check to see if it is true-to-type. Primulas crop up in many different places—parks, bedding polyanths, pot primroses for Mothering Sunday, the lovely wild birds-eye primroses of the north of England and Scotland, and, further, North America.

Primulas start to flower as early as January. One of the first we have on the nursery is a form of *Primula megasaeafolia* collected recently by George Smith. It has large, deep magenta flowers, and comes from Turkey. Previously this species has been found to almost defoliate in winter and looks extremely scruffy, this is a much better collected form we got hold of last year and are now building up stocks. It flowers continuously from January through to March and in addition has super rounded leaves.

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Primula bhutanica 'Franklin form' is an extremely vigorous form of *P. bhutanica,* a species from the petiolaris section of primulas. Growing the petiolaris primulas is almost impossible in the south of England because of the low rainfall but in the north the rainfall is sufficient for their needs. In the wild these grow almost behind waterfalls where there is a constant moist atmosphere and they never dry out.

Primula gracilipes, also in the petiolaris section is again one of the first to flower, you can often have it in flower for Christmas day and it will go right through until about the end of April. It is practically the far eastern version of our primrose, with lovely tight clusters of flowers—up to 100 flowers in each rosette. To keep these in healthy growth you have to divide them, and it is important to stress this to customers. This should be done at least every other year, from September when the nights are cooler, then they grow away really well. After splitting them up, put them into a closed frame for two or three weeks. By then they have taken root into the new compost and will carry on growing right through the winter.

Another group of primulas making a marvelous show in spring are the European primulas. These have given rise to many hybrids in cultivation, and lots of wild hybrids. George Smith has collected some lovely wild forms from the Alps but there are also some extremely good forms in cultivation from garden raising, collectively known as the *Primula* × *pubescens.*

Primula marginata, which has predominantly farina-covered foliage with a saw edge and purple blue flowers also comes in various different forms, a very dark form of this being Pritchards variety. Holdens variety, raised by my predecessor at the nursery, has very deep tooth serrations. A tremendous amount of variation can occur within that single species without any hybridisation at all. These propagate quite freely but it is essential to ensure stock plants are true-to-name because they are divided in summer when there is no flower. We ensure each plant is labelled and after about three years we scrap the stock plant and bring young stock in from the young stock frames to get new stock plants. This keeps vigour in the stock all the time because if you keep splitting up the same plants you tend to lose vigour quite readily.

You do have to watch out for virus. One of the most susceptible primulas is *P.* × *pubescens* 'Beverly White'. Most of the others tend to stay quite clean.

We have just got stock of one of the *P. allionii* hybrids, 'Margaret', a fairly new one to me, although it got an RHS Award of Merit in the early 1960's. It is a *P. allionii* cross with P. ×pubescens and a really dwarf compact cultivar with a lovely white eye.

Another super one is called *P.* 'Beatrice Wooster', *P. allionii* crossed with *P.* 'Linda Pope' *P. marginata* hybrid. It is a prolific hybrid with quite a tooth edge to the leaf but no farina and is quite freely available in the alpine trade. These are best grown as pan plants in the alpine house. Once they have finished flowering they can be put out in the weather. Plenty of rain doesn't hurt them but to keep the flower in top condition give them cover in the early part of the year to preserve the condition of the leaves with the farinaceous types. The wild form of *P. auricula,* as it occurs in the Alps, has a small white eye in the centre of the flower, and a very sweet scent which has been passed on to the many hybrids that have been raised over the last 100 to 150 years.

P. marginata, has beautiful farinaceous foliage, especially if it is given cover during the first months of the year. *P. marginata* 'Coerulea' is a pale blue version, with lovely toothing to the foliage. It goes down to dormant resting buds in winter and then emerges around the end of February or early March. The rootstock is quite woody, and in the wild they tend to grow in crevices in cliffs where the woody stems will grow almost a foot in length, with quite a woody base. These can be cut back for propagation purposes and we sometimes just chop back the tops to use as cuttings or divide and take away base offsets that have already rooted. These cut back stems will readily re-shoot.

There are many hybrids around in cultivation now and tissue culture has made a lot of scarce old cultivars, which are very shy to throw offsets naturally, much more freely available.

'Mohave' is a lovely one with beautiful farina-covered foliage, a clear white ring of paste in the centre. Another which is extremely well named is 'Neat and Tidy', again with a lovely clear eye in the centre of a very dark coloured flower and the foliage is very white.

'Greta', is one of the green-edged cultivars. Some of the green-edged types tend to hold the petal flat back so you can see the green margins; some of them, like 'Greta', tend to curl inwards.

The farinosa section includes *P. elliptica.* It is quite an early flowering one, early April, and sets a large amount of seed. On the nursery we never seem to be able to catch the seed on time and have to collect seedlings from around the parent plant. Seeds germinate quite freely in this situation.

If you sow primula seed the worst thing to do is give it heat. Sow as early in the year as possible in cool conditions and the minute germination takes place take off any glass cover.

The candelabra primulas cover a vast range of different species and hybrids, naturally occurring ones as well as cultivated types. *P. helodoxa* is a very bright yellow species, with whirls of flower all the way up the stem. It hybridises quite freely if not kept in isolation. Candelabra primulas need ample moisture with stream side or bog garden conditions. *P. poissonii* is one of the latest types of the candelabras to flower, going right into June and early July and growing up to 60 cm or even 90 cm tall.

One of the hybrids that has to be propagated vegetatively rather than from seed is the Inverewe hybrid, a lovely deep fiery red. It will not come true from seed so you have to propagate by division.

Among the bell group of primulas is the sikkimensis section, including *P. sikkimensis* itself. 'Tilmans No. 2' is the seed strain, very sweetly scented with quite a delicate slender stem but quite a tough little primula in its own right and a lovely deep yellow flower.

P. vialii, the red hot poker primula, is lovely with a graceful flower spike, purple flower buds and pink flowers.

P. capitata is a later flowering one, often going on into the autumn. It has lovely farina during winter on the evergreen rosettes. Recently collected by Peter Cullinton at Ness Botanic Garden, Cheshire, is *P. capitata crispa* which holds its flowers all to one side of the head and has much deeper colouring.

P. florindae is one of the last primulas to flower. Colours are lovely deep reds and oranges, and scent is very spicy. It is very strong growing, with cabbagey leaves, and grows to a height of 1.0m or even 1.3m tall.

Production. We sow the seed in small quantities, because primulas germinate very readily indeed, and the minute they are large enough to prick out we take the lights out and get them into seed trays. The thing is not to have any check in growth.

A frame full of seedlings pricked out in early July takes about two months before foliage completely covers the boxes and they are ready for potting for flowering the following spring. The plants are grown fairly open; we try to cover them as little as possible although the early flowering ones are given cover during the winter. They should still be well ventilated except in the most extreme frosty conditions. They will tolerate anything down to −20°C quite easily.

We have done *P. oriator* from micropropagation but growth is very weak. But another type that we do from micropropagation are the double-flowered primroses which flower at various times of the year and make acceptable and vigorous plants.

Seed collecting should be done with the seed heads just ready for bursting. The only one that we actually sow green is the petiolaris primulas—if we collect the seeds; we sow them immediately the day we get them, since they do not store well at all.

Stock plants. Everything is grown in pots and repotted about every other year to keep them in good health. At the same time an insecticide is incorporated to control vine weevil. A drench had been used for the last couple of years but we found this quite ineffective. Aldrin is now the only treatment recommended by the Ministry of Agriculture because drenches seem to be no good at all. We are going back to using compost incorporation of Aldrin. It will last for about three years and gives quite good protection.

EUPHORBIAS: EUPHOBIA AND EUPHORIA

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Euphobia. What exactly *is* a euphobia? According to my dictionary a euphobia is a foolish or feeble excuse put forward by ignorant people as a reason for not growing that excellent race of plants called euphorbias. So what are these excuses or reasons? Why should anyone not want to grow euphorbias in their garden?

The first excuse is that they are poisonous. That's my excuse anyway. I used to grow nearly 50 different kinds, and my garden is only small, but having so many poisonous plants was a problem and I gave a lot of them away.

The truth is that they are not *very* poisonous. They're not like aconites, where one bite on a root and whoops—you've had it! The poisonous part of a euphorbia plant is the white, milky juice which every part of the plant contains. This juice is also a good method of identification. If it has white milky juice its likely to be a euphorbia. If it hasn't, it isn't.

The effect of euphorbia juice is to cause severe inflammation and swelling. Deaths have been reported in connection with *E. peplus*, the very common petty spurge, which most of us have in our gardens whether we like it or not, and also with *E. helioscopia*, the sun spurge, another common weed, which is more often found on disturbed wasteground, rather than in gardens. The sun spurge, by the way, is one of the comparatively few plants with a world-wide distribution. But I imagine that these deaths were caused by actually managing to swallow a reasonable quantity of the plant—and this is something that would be quite hard to do, because the effect of euphorbia juice on the mouth would be so unpleasant that any rational person would react violently and spit out everything as soon as they could.

But the juice of euphorbias is also harmful in contact with the skin and it is worth taking reasonable precautions to prevent this. This is because the juice contains co-carcinogens. It would not necessarily give you skin cancer. The damage might be transferred to some other organ. So if you do get the juice on your hands, which are liable to if you are thinning or weeding out euphorbias, wipe it off immediately, or better still wash your hands. The ideal thing is to wear gloves. The juice is also harmful to the eyes.

The second excuse for not growing euphorbias is that many of them are not reliably hardy. North of Birmingham you are liable to lose some plants in the average winter, especially in exposed or frosty gardens. One bad frost can be the critical factor in losing your plants.

The following are worth trying in cold gardens: *E. amygdaloides, E. amygdaloides* 'Rubra', *E. capitulata, E. cyparissias, E. griffithii, E. epithymoides* [syn. *E. polychroma*], *E. villosa, E. serawschanica* and *E. soongarica.*

A third reason for not growing euphorbias might be that they are invasive. Fortunately the majority of the most attractive species are well-behaved, but some are not. *E. cyparissias,* for example, is colourful, starts early and blooms for weeks and has attractive feathery foliage. But it spreads so annoyingly by underground runners during the winter that most gardeners end up considering it a menace.

If you have an aunt, or a customer, that you particularly object to, try giving them *E. stricta,* the Tintern spurge, as a present. One seedling from this and the whole garden will be covered from end to end in the Tintern spurge. You can still be pulling up seedlings five years later. It's quite pretty, though, especially when it's going to seed. Other invasive species are *E. dulcis, E. esula, E. pseudovirgata* (sometimes called *E. uralensis*), *E. waldsteinii* and *E. lathyris.*

Euphoria. This is presumably a pleasant state of mind induced by successfully growing euphorbias. The first good thing about euphorbias is that they are easy to propagate.

Many of them can be easily divided. Those which spread by underground runners, such as *E. cyparissies* and *E. waldsteinii* are simple. April is the best time, before they are too large. Species which form central clumps, like *E. polychroma, E. palustris,* and *E. villosa,* can be lifted after flowering and cut carefully with a knife.

Almost all can be easily grown from seeds. Seeds must be collected by putting paper bags over the flower, because the seeds are violently dehisced and land some distance away. The seeds should be sown the following spring while still fresh. After two or three years they lose their viability because they dry out too much. The seeds are also poisonous.

The best way I've found of sowing euphorbia seeds has been to put a 3cm layer of peat based compost in a covered tray in the dark with some heat. It is important to inspect at least once a day, preferably twice. Otherwise the seeds will germinate like grass and being in the dark will grow tall and spindly and then keel over. As soon as the seeds germinate they should be given light and air, and not be allowed to get too damp.

Cuttings are also possible of selected cultivars, though not so easy as division or seeds.

The second good reason for growing euphorbias is that many of them are among the first perennials of the year to bloom. In fact some, like *E. characias* provide some interest during mild winters when the flowering stems can be seen poised ready for growth and flowering.

Not only do euphorbias start early but they also go on for a long time, blooming for many weeks on end, gradually fading in colour. Then there are some which bloom later, such as E. *nicaensis* and E. *sikkimensis*. From a commercial point of view this ability to be colourful early in the year is an advantage. Anything that is in bloom when the spring frenzy hits the garden centres must surely be worth trying.

Euphorbias tolerate being in pots for long periods very easily, providing they are protected from frost. What more can I say in favour of euphorbias? Flower arrangers adore them. All good plantsman grow them. They are fashionable flowers, like hellebores, old-fashioned roses, and grey-leaved plants. There are, I regret to admit, about 1800 species of *Euphorbia*. Anyone who tries to collect them must be slightly demented. Luckily however most of them have never been introduced. Their dried leaves lie pressed between papers in the herbaria of the botanic gardens, while the native plant itself grows in some remote spot in Uzbekistan or Ulan Bator.

Many of the 1800 are cactus-like. Others are like the poinsettia. I have always limited my interest to the hardy herbaceous species of which there are about 50 in cultivation.

Most euphorbias are easy to cultivate. On the average they do well under Mediterranean conditions, a sunny position and well-drained soil. But most are quite tolerant. As long as the soil is not water-logged they can cope. E. *palustris* even does well in damp shade. For detailed cultivation advice I must refer you to my article in the *Plantsman* (Royal Horticultural Society) of December 1983.

There are several species or cultivars which deserve to be in greater supply (commercial propagators please note): E. *amygdaloides* 'Rubra' (Kew form), E. *characias* var. *sibthorpii*, E. *griffithii* 'Dixter', E. *nicaensis*, E. *orientalis*, E. *polychroma* 'Emerald Jade' and E. *rigida*.

GROUND COVER ROSES

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Roses reached the peak of their popularity in the U.K. during the 1960's. The level of imports of rose rootstocks (Table 1) illustrates this fact reasonably accurately, but from 1974 we must also take into account the amount of home-produced stocks. This home production was made possible following work carried out by Dr. Blundell at Bangor University and was industry funded through the Rose Growers Association. An investment by the industry of one or two thousand pounds is now saving half a million annually.

The popularity of the rose declined during the 70's for a number of reasons, the most significant being (a), the need to spray regularly against mildew, blackspot and rust and, (b) the loss of two larger than life rosarians and promoters of roses by the death of Harry Wheatcroft and by emigration to New Zealand of Sam McGredy. I believe the popularity of the rose is due for revival, and sales may again reach 40 million per year. These increases will be brought about through the introduction of three groups of disease resistant cultivars, introduced for special purposes.

Table 1. Approximate numbers of rose understocks planted annually in the U.K. (millions)

Year	1965	1966	1968	1971	1974	1977	1980	1983	1986
Imported	40	61	52	45	29	21	20	17	10
Home produced	—	—	—	—	10	11	10	10	13
Total	40	61	52	45	39	32	30	27	23

Miniature roses. Miniature roses are most suitable for indoor/outdoor pot culture. This market is already increasing quickly and is dominated by the Minimo range of Dr. Reuter of Holland and the Meillandina range from Meilland of France. These roses are being sold in 3" and 4" pots marketed on a large scale through garden centres and superstores. It is appropriate to note that the term "miniature" refers to the size of the flower and not to the size of the plant although they are generally small growers.

Patio roses. These are compact multiflora, floribunda, or clustered flower cultivars which have significant potential for bedding plants, for use in window boxes and confined places in the private garden. The ideal patio rose will have H. T.-shaped flower buds, weather-resistant flowers, scent, good repeat qualities, disease resistance, and compact growth. Most of the recently introduced cultivars have one or two of the qualities but rarely more than three. There is a lot of activity in breeding these cultivars and I am sure they will quickly be improved.

Ground cover and landscape roses. In recent years the potential of this group has been highlighted with the introduction of a number of new vigorous growing cultivars, which have significant potential for large scale landscaping. At the same time the new introductions have highlighted the qualities some of the older and well-tried cultivars such as 'The Fairy', 'Frau Dagmar Hastrup', and 'Max Graf'.

Most of the recent vigorous cultivars are disease resistant but generally because of the dominance of *Rosa wichuraiana* in their background are generally only once-flowering. They are ideal for large scale planting and for use in private gardens where there is plenty of space, or are required to smother difficult terrains such as banks. However, the full potential of ground cover roses will not be realised until we have a range of repeat flowering cultivars, which by the very nature of recurrent flowering will produce less vigorous growth more suitable for small gardens.

One cultivar, 'Snow Carpet', raised by Sam McGredy already meets these requirements and is selling in large quantities through garden centres. Five hybridists are currently putting a lot of effort into raising new ground cover and landscape cultivars, namely Kordes of Germany, Meilland of France, Illsink of Holland, Poulsen of Denmark, and to a lesser degree, Dickson's of Northern Ireland.

Propagation. All three groups are easily propagated on their own roots, which also makes them ideal subjects for pot culture. The fact that they are easily produced on their own roots is very significant when it comes to predicting who will propagate and grow the final product. In the past the rose trade has been dominated by a number of rose specialists who, by tradition, produce plants budded onto *Rosa laxa* and forms of *Rosa canina*.

In the future specialist propagating and liner nurseries will probably produce the liners while traditional container nurseries are best equipped to produce the new final product. The recently introduced cultivars are generally so easy to propagate that the type of cutting and system used will be the one that fits into the existing propagating system.

Direct rooting of very short single node cuttings, three or four cuttings per pot under polythene tents, will be probably just as effective as large 3" to 4" long root cuttings rooted in cutting trays under mist or fog. It would appear that materials taken from young plants indoors may prove to be more easily rooted and freer of contamination than those collected from outside. The possibilities of hardwood cuttings also needs close attention, as Meilland uses this technique effectively in Seville.

Micropropagation. This is already proving to be playing a part in the production of miniature and ground cover roses with spectacular multiplication rates of times five, with the result that micropropagation may prove to be a very significant tool in volume production of ground cover roses.

Own-root ground cover roses have the significant advantage that suckers are a thing of the past and with perpetual flowering cultivars it will in the future be quite feasible to prune by mechanical pruners and flail mowers, followed by gathering up the prunings by vacuum cleaners, which will open up the market for large scale use. Costs of both planting and maintenance will be cheaper than turf. Scent and heps are additional qualities. Cultivars 'Grouse' and 'Partridge' are particularly heavily scented, as is the rugosa cultivar, 'Moje Hammarberg'. While everyone is familiar with the heps of 'Frau Dagmar Hastrup' and other rugosa cultivars the less dramatic heps of 'Grouse' and 'Partridge' should also be taken into account.

The growth habit of ground cover roses can be divided into three types: prostrate, mound forming, and arching. These can obviously be further divided into vigorous and less vigorous.

The different habits of growth can be put to good use in the landscape to give height and reduce monotony. They will all form a complete canopy over the ground in time but at different speeds, and it is therefore important the designer is aware of the plant habits to ensure that a complete canopy is formed in reasonable time.

Examples of cultivars are:

Prostrate: 'Grouse' 'Partridge', 'Max Graf Red', 'Max Graf Pink', Max Graf White', 'Snow Carpet' (less vigorous).

Mound forming: 'Pink Bells', 'Red Bells', 'White Bells', 'Bonica'.

Arching: 'Pink Wave', 'Ferdy', 'Red Blanket', 'Rosy Cushion'.

EARLY EXPERIENCES WITH A FOGGING UNIT: AGRITECH

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The modification of relative humidity to a point where "fog" is produced is not new. "Humidifiers" and fine droplet sprays have been used for many years to ameliorate the effect of high temperatures under various structures during daytime, for frost protection at night and the control of relative humidity in cold storage. All of these practices rely on the fact that a large amount of latent heat is required to change water from either the solid to liquid or liquid to the gaseous state; the spin-off being a change in temperature.

Most of the equipment was very large, often expensive, and in many cases used only on a large scale and was, therefore, not seriously considered by propagators, particularly those with comparatively small facilities. Recent developments in the range of equipment available have changed all this.

Now we have not only the ongoing fog versus mist debate, which in itself is not new, (over 20 years ago Warner (2) recognised this in his paper to the IPPS Eastern Region Conference of 1966 at Newport, Rhode Island), but have extended the argument to include types of fog. We consider whether the product is 'dry' or 'wet', whether ventilated or non-ventilated, whether closed or open (i.e. under polythene or in an open house) and proceed to compute in combinations of this new propagators' jargon.

There is a danger that the basic principles of simple systems such as closed cases and the use of polythene sheeting are overlooked in the rush to greater and more involved technology.

The difference between fog and mist. Fog is minute droplets of water, so fine that they remain suspended in the air (as opposed to mist where the larger droplets precipitate out very rapidly falling on to the surface of whatever subject is being misted). This is the fog that we can see. There is also the effect of a near-saturated atmosphere where the fog has raised the relative humidity but because of the temperature the droplets cannot be seen. The important thing is that fog being in suspension moves with the air around the whole surface of the plant and, very importantly, underneath the leaves of our cuttings where the majority of the stomata are to be found. It is this important factor that provides the basic difference between a fogging system and a damping down or misting system which can only reach the upper surfaces.

The performance of the cutting will be influenced by its ability to photosynthesise during the rooting period, enabling the rapid developments of both shoot and root throughout the propagation period to the enhancement of the size and quality of the rooted plantlet. Actively photosynthesising plants can utilize any nutrients that may be available in the rooting medium, thus opening up a wide range of possibilities for enhanced propagation techniques. This factor is particularly important during the 'high-light' summer propagating season and the use of fog in winter under 'low-light' conditions does not utilize these factors and may be fraught with additional problems.

Why use fog? My own interest in the technique developed as a result of attending the I.P.P.S. Southern Region Conference in 1980 where the equipment which came to be known as 'Agri-Tech' was discussed and described by Dan Milbocker (1). It was comparatively cheap and could be used in relatively small areas, a single fogging machine being capable of covering an area of 90 sq m. This was just what I needed. Our 15-year-old mist unit which—because we were in a hard water area—relied on collected rain water, which was then pressurised in order to function, needed replacing. The pump and pressure unit alone would have cost more than the 'Agri-Tech' fogger and recent experiences with the idiosyncrasies of the system made the choice very easy. However, things were not quite so simple: voltages and cycles are different in the USA where the 'Agri-Tech' came from and the equipment had to be modified. This proved to be quite costly and time-consuming. However, the end product worked just as Dan had predicted and I have had no reason to regret my decision to change to fog. I would have been happier if the Mark I model I obtained had been more robust and more durable, but I understand there are now improved models with more certain performance. One thing I have learned is that a back-up system is essential because it is a certainty that the machine is bound to fail on the hottest day of the year just after taking a batch of one's choicest, most difficult material. I find no great pleasure in attempting to change electric motors when the temperature is running up and all around are desperate wilting plants. We have come to terms with this and now have a simple emergency system as an insurance against rapid crop loss.

Our objectives. Our first objective was initial cost saving on the equipment which, in spite of the problems, was not extortionately high (in 1980 the dollar was 2.40 to the British pound) and our whole installation, including shipping, electrical work and the rewiring of one motor came to under £600. More important is the saving on running costs. Much of the energy that goes into undersoil heating is used to evaporate the surplus water in the compost in order to maintain the necessary bottom heat. This is particularly so where mist equipment is used to maintain cuttings in a turgid condition, often in high air temperatures which require considerable amounts of water to be used. Much of this surplus saturates the medium reducing its temperature and absorbing high quantities of energy due to the latent heat consumed in evaporation. This is not a problem where fog remains in suspension and it is possible to maintain high air porosity within the medium while the surrounding atmosphere is controlled even at very high temperatures. In fact, in high temperatures the rooting medium may well tend to dry out. Cost savings on under-heating in our first year were at least 50 per cent.

Our second objective was to provide a controlled environment for the weaning of propagules from micropropagation laboratories. At that time micropropagators were experiencing serious difficulties in the transition of material from the closed conditions of the laboratory to the outside world. Losses were extremely high and it was felt that an intermediate stage was needed either as a service to the producing laboratory or as a buffer for the growing-on operation. Fog has much to recommend it in this situation. However, the production laboratories have recognised this weakness and are now taking their material through this stage and offering the weaned and established plantlet or liner.

Our experience over the last six years has pointed to one factor that initially we had been slow to recognise and that is the superior quality of the rooted cutting or liner that we are producing.

Many of our plants now root rapidly and produce stronger, more vigorous liners which most certainly influence the quality of the final product. This cannot be attributed solely to the use of fog but in combination with improved open media (bark and perlite plus peat mixtures) and a modification in the type of cutting material used, particularly in the soft summer season. These factors have produced a throughput far in excess of that previously regarded as acceptable under mist and polythene. Even simple subjects such as fuchsias and hydrangeas can be improved upon, produced quickly and cheaply and, most important of all, with a greater efficiency of operation.

The range of subjects that we have rooted to acceptable economic levels include soft spring cuttings of *Acer* and *Betula*, deciduous azaleas (using pre-treated or forced material), *Cotinus*, *Corylopsis*, and our main evergreen azalea crop, together with *Liriodendron*, *Buddleia* and *Prunus* during midsummer. We have also rooted semi-ripe cuttings of *Parrotia*, *Pieris*, and *Rhododendron*, both dwarf species and hardy hybrids, and a wide range of high-value evergreens, including *Mahonia*, *Eleagnus*, *Kalmia*, and *Camellia*.

We have found that conifer cuttings in general do not root well, particularly when taken during the winter months. However, it is not difficult to use the facility without the fog switched on or to control it on a purely manual basis during warmer or brighter periods.

CONCLUSIONS

Always remember your objective. If you have a system that is working well do not change to fog just because fog is there. Remember also the basic principles. No quantity of highly developed electronic equipment can replace good propagation practice. It is essential to have good propagation material at the correct time of the year, to use a well-balanced medium and accurate temperature controls, both of the medium and the atmosphere above and, above all, to practice good hygiene standards; diseases or pests will move very rapidly through a fogging area particularly in warm summer conditions when there is considerable air movement. Observe these basic principles and your fog system will work very well. You will be amazed at the speed of throughput and the quality of the resultant product.

LITERATURE CITED

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PROPAGATING SITKA SPRUCE UNDER INTERMITTENT MIST AND OTHER SYSTEMS

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Abstract. The reasons for the recent interest in using stem cuttings of tree species to produce rooted cuttings for forest use are reviewed. In Britain, commercial developments are currently confined to Sitka spruce (*Picea sitchensis* Bong. (Carr.)). A prototype facility for rooting conifer cuttings is described. Results indicate that high rooting can be obtained in a wide range of media and under different propagation systems. Correct feeding of the mother plant is shown to be important in obtaining high quality cuttings. Future developments are reviewed.

INTRODUCTION

Plants of tree species used in commercial forestry have traditionally been raised from seed. Only poplars and willows have normally been propagated using stem cuttings and in Britain these are a very small percentage of the number of plants produced. However, in the last 15 years, there has been increasing interest worldwide in the vegetative propagation of a wide range of other tree species (8). This has occurred for 3 reasons. Firstly, tree breeders have begun to identify high yielding genotypes with appreciable gains over unimproved stock. Such genotypes are generally working well do not change to fog just because fog is there. Remember also the basic principles. No quantity of highly developed electronic equipment can replace good propagation practice. It is essential to have good propagation material at the correct time of the year, to use a well-balanced medium and accurate temperature controls, both of the medium and the atmosphere above and, above all, to practice good hygiene standards; diseases or pests will move very rapidly through a fogging area particularly in warm summer conditions when there is considerable air movement. Observe these basic principles and your fog system will work very well. You will be amazed at the speed of throughput and the quality of the resultant product.

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INTRODUCTION

Plants of tree species used in commercial forestry have traditionally been raised from seed. Only poplars and willows have normally been propagated using stem cuttings and in Britain these are a very small percentage of the number of plants produced. However, in the last 15 years, there has been increasing interest worldwide in the vegetative propagation of a wide range of other tree species (8). This has occurred for 3 reasons. Firstly, tree breeders have begun to identify high yielding genotypes with appreciable gains over unimproved stock. Such genotypes are generally available in very small numbers and thus cannot be grown from seed quickly in commercial quantities. Secondly, the advent of reliable mist propagation systems has made it possible to consider propagating these genotypes economically on a large scale. Thirdly, an improved understanding of problems involved with maturation has resulted in great emphasis upon propagating juvenile material that is relatively easy to root, and grows vigorously in the forest.

In Britain, systematic research into the vegetative propagation of conifers began in the 1970s (4, 12). Species of particular importance were Sitka spruce (*Picea sitchensis*), and hybrid larch (*Larix* × *eurolepis*). Results with Sitka spruce have been very successful, leading to commercial uptake of the technique by the early 1980s. Over one million rooted cuttings of improved Sitka spruce will be planted in forests in 1988 and this could reach five to ten million by 1995 (13). Progress with hybrid larch has been slower, but reliable rooting methods have now been developed (11) and the limiting factor is shortage of tested high quality seed. Small trials have been carried out to examine propagation of a wide range of other commercial conifer species, and most have proved easy to root using the techniques developed for Sitka spruce (12).

Conifers grown from seed are a relatively low value product selling at six to eight UK pence per plant in 1987. At current levels of genetic gain, Sitka spruce cuttings must be produced at no more than two to three times that of standard stock. This means that costly propagation facilities and techniques used in other areas of horticulture may not be justifiable economically.

A comparatively large propagation facility to test techniques at a scale more appropriate to commercial practice has been developed since 1981 at Newton Nursery near Elgin, Scotland, and has proved a valuable testbed for large scale conifer propagation. This paper describes the facility and a number of experiments performed in it.

PROPAGATION FACILITY

The facility consists of one polythene mist house (Table 1), a double skinned polythene house, 24m by 8 m, for rearing stock plants; plus ancillary standing-out beds and potting sheds. Rooting capacity is one crop of about 100,000 cuttings per year. Up to 300 stock plants can be raised indoors and a further 500 outdoors.

The mains water supply at Newton is both relatively soft and maintains comparatively high pressure although this can fluctuate in dry seasons. Thus neither acidification of the water nor a break-tank was necessary. Good misting was achieved by dividing the system into a set of six banks and activating them in sequence. The present nozzles have improved misting cover and their nondrip valves are also an advantage. The locally designed mist control unit works well during the rooting phase. It is less satisfactory during weaning when some water must be supplied at regular intervals irrespective of ambient conditions. The photocell-based unit is more appropriate at this stage since it is not so sensitive to ambient humidity.

Our major mistake has been the failure to level the site initially, since moist air tends to flow from the top of the house to the bottom and crops at the top can dry out more. However we normally expect at least 85 to 90 per cent rooting in Sitka spruce and 75 to 85 per cent in hybrid larch. Five to 10 per cent of these are not used due to poor roots or other defects.

PROPAGATION METHODS

Seed of the desired genotypes is germinated in a greenhouse and the resulting seedlings are grown on for 2 years to produce stock plants 50 to 100cm tall (see Mason, 1984 for details). Cuttings are collected from these plants in late February to March prior to flushing. They are normally 8 to 10cm long and are inserted without a rooting hormone, stripping of basal needles, or wounding, for rooting under mist. Base heat is generally not used. A wide range of media can be used provided they have a minimum of 15 per cent porosity. Cuttings flush shortly after insertion, making 2 to 5cm of growth during the rooting phase. Callusing is seen by 8 to 10 weeks, and root development from 10 to 12 weeks. Cuttings are weaned by 20 weeks and are lifted and lined out in the open nursery. They are grown on for a further 18 months to a height of 30 to 40cm. Cuttings can then be taken from the first cycle material and rooted in their turn. Normal multiplication factors over two propagation cycles are between 250 and 500 times, making it possible to produce around one million plants from an initial batch of 2,500 seedlings. More than two propagation cycles are not yet advised, largely because of fears of a reduction in the genetic base through differential loss of juvenility. However, recent work shows no decline in rootability over 5 cycles (5), findings which are supported by work in Germany on Norway spruce (14).

EXPERIMENTAL DETAILS

Experiment 1. First cycle cuttings of Sitka spruce were inserted in 24 different media. These were made by using the mixtures and proportions shown in Table 2. Components of the media were a medium-grade sphagnum moss peat (P), a coarse lime-free grit of 2 to 3mm average particle size (G), a fine lime-free sand (average size 0.05mm) (S) and a fine (<8 to 9mm) composted pine bark. The experiment was a split-plot design with the 24 media main plots replicated 5 times. The main plot size was 40 cuttings at 4cm spacing in a seed tray (40cm × 27cm × 7cm). Main plots were split for assessment at 14 and 20 weeks after insertion. Aeration of the

Table 1. Newton misthouse specifications.

Dimensions:	36m × 6 m.
Water supply:	Mains (pH 7.4 but negligible $CaCO_3$; conductivity 100 μS/cm).
Mains pressure:	5–6 kg/cm^2.
Bed heating:	Electric cable (300 W) in one small section (5 m^2) for experimental purposes (60 w/m^2). Maintains 3–5°C above unheated bed.
Mist control:	(a) Own design based upon a relative humidity sensor sited in middle of house; (b) MacPenny* Solarmist based upon a photocell.
Mist system:	6 banks of 8 Brumiflore* blue tip nozzles. Each bank consists of 2 sets of 4 nozzles. The nozzles are mounted at 1.2m apart and 1.5m above the bed.
Pipework:	Mist nozzles are mounted on copper pipe 12mm diameter. Remainder is alkathene.
Mist activation:	Banks are operated in sequence through a central control.
Misting frequency:	Aiming to maintain 95% RH during rooting, declining to 50–60% during weaning. Frequency varies according to ambient conditions, but on warm days in May might be 5 second burst every 2–3 min. Mist switched off at night.
Propagation beds:	32m × 2.5m wide. Beds are 30cm deep with bottom layer of sand/gravel and 8–10cm of rooting medium.
Rooting medium:	Originally 80% lime-free grit (2–3mm) and 20% sphagnum moss peat. Now 50% composted pine bark: 50% sphagnum moss peat plus a further 20–30% added lime-free grit (2–3mm).
Shading:	50% Lobrene* shading from early May–July. Sides are pegged out like a flysheet to reduce heat transfer.
Ventilation:	(a) fan (440 W) used throughout growing season. Set at 25°C; (b) skirts of Lobrene* 1m high along sides. Used to harden cuttings immediately prior to transfer outside.
House orientation:	Long axis runs approximately north-south. There is also a 2.5m fall from the south end to the north.

*Commercial names are quoted for information only and do not represent an endorsement by the Forestry Commission

media was calculated as percentage macropore space (16). Cuttings were inserted on 27 February 1984.

Experiment 2. Second cycle cuttings of Sitka spruce were collected from first cycle material that had received four different top-dressing regimes after lining-out in the nursery. All treatments received a basal dressing of PK (0-24-24) at 500 kg/ha prior to lining out. The regimes were an unfertilised control (SC), a high nitrogen regime (SN: 168,14,42 units of NPK from March–September), a balanced regime with moderate levels of NPK (SB1: 135,135,180 units of NPK), and another balanced regime applied at twice the rate (SB2: 270,270,360 units of NPK). First cycle cuttings (F) were also included: these were collected from stock plants grown under standard regimes. A randomised block design was used with five treatments replicated five times. Each plot consisted of 45 cuttings inserted at 4cm spacing in an 20:80 sphagnum moss peat; grit (2 to

3mm) medium. Cuttings were collected and inserted on 21 March 1986 and assessed after 18 weeks.

Table 2. Experiment 1. Composition of rooting media.

Mixtures		Proportions (% by volume)
Peat/grit		
Peat/sand		80:20
Peat/bark	×	60:40
Bark/grit		40:60
Bark/sand		20:80
Sand/grit		

Experiment 3. First cycle cuttings of Sitka spruce were inserted in five different media both in the Newton mist houses (N) and in 3 contrasting propagation houses at Banff and Buchan Nurseries at Portsoy, Scotland. These houses were (W) a white polythene house with a propagation bed heated to 18°C, a white polythene house (L) with cuttings sealed in a white polythene cloche and (C) a clear polythene house with cuttings in a white polythene cloche. All treatments in the Banff and Buchan houses were hand watered daily. The five different media were combinations of sphagnum moss peat and a coarse lime-free grit (2 to 3 mm). Three replicates of each of the medium treatments were placed in each of the houses. Cuttings were inserted at 4cm spacing in similar seed trays as used in Experiment 1 with 45 cuttings per tray. Cuttings were collected and inserted on 1 March 1983 and assessed after 20 weeks.

ANALYSIS

Each cutting was assessed after lifting for the presence or absence of roots to give rooting percentage. Root volume was assessed as a root score of 1 to 10 (low to high) using photographic standards. A root of 4 or 5 is roughly equivalent to the root volume found on a good one-year seedling. Both rooting percentage and root score were analysed by standard analysis of variance procedures with percentages being subject to an arcsin transformation.

RESULTS

Experiment 1. The major effect in this experiment was that of the various media mixtures. Significant differences were found among the mixtures, particularly at the 14 week harvest (see Table 3). The effect of differing proportions was much less than that of the various mixtures. At 14 weeks, the differences were largely due to the superior performance of the peat-bark combination which was significantly ($p<0.05$) better than all except bark-grit for rooting percentage and all except bark-grit and peat-sand for root score. At

20 weeks, peat-bark was still the best treatment, but only rooting percentage in peat-sand and sand-grit was significantly poorer. Rooting percentages were high overall and the major improvement from the peat-bark was in speed of rooting. Examination of the percentage macropore space results revealed that good rooting performance was closely linked to adequate aeration and drainage since all mixtures with bark showed much higher values. A minimum value of 15 to 20 per cent macropore space seems desirable.

Table 3. Experiment 1. Effect of media mixtures on rooting of Sitka spruce cuttings.

14 weeks						
	Peat/grit	Peat/sand	Peat/bark	Bark/grit	Bark/sand	Sand/grit
Rooting %	78	75	95	94	84	77
Root score	2.4	2.6	2.8	2.5	2.4	2.3
Variance-ratio test: rooting percentage ($p<0.001$), root score ($p<0.001$)						
20 weeks						
	Peat/grit	Peat/sand	Peat/bark	Bark/grit	Bark/sand	Sand/grit
Rooting %	95	92	100	98	96	92
Root score	6.7	6.8	7.1	6.9	6.5	6.7
Variance-ratio test: rooting percentage ($p<0.05$), root score (ns)						
Macropore space (%)						
	Peat/grit	Peat/sand	Peat/bark	Bark/grit	Bark/sand	Sand/grit
%	12.5	6.5	26.3	25.5	25.0	12.5

Experiment 2. The results (Table 4) showed that fertiliser regime had an important influence upon the subsequent rooting performance of second cycle cuttings. Thus SB1 (moderate nutrition using NPK) showed significantly higher rooting percentages than SN and SB2 (high nitrogen and high NPK). When second cycle cuttings were compared with first cycle material (F) only SB1 did not show significantly lower rooting percentage and root score.

Table 4. Experiment 2. Effect of nursery fertilisation on rooting of Sitka spruce cuttings. (See text for explanation of codes.)

	Rooting performance				
Treatment	F	SC	SN	SB1	SB2
Rooting %	99.2	95.2	90.2	98.4	90.8
Root score	4.9	4.2	4.2	4.4	4.2
Variance-ratio test: rooting percentage ($p<0.01$), root score ($p<0.05$)					

Experiment 3. Rooting percentage was very high at Newton and nearly as high at Banff and Buchan. Analysis of the results showed different trends between regimes for rooting percentage as opposed to root score (see Table 5). There were highly significant differences among media ($p<0.001$) and there was a significant

media house interaction ($p<0.05$). A quadratic regression was fitted to the data from each house to see which medium gave the best results. For the Newton house (N) there was no difference among the various media. The regression was significant for the Banff and Buchan houses ($p<0.01$) and suggested maximum rooting percentage between 75 per cent grit 25 per cent peat, and 50 per cent grit 50 per cent peat. The only significant differences for root score were between the media ($p<0.001$) with 50 per cent grit 50 per cent peat giving the best result. Fitting a quadratic regression indicated a maximum mean score at around 45 per cent grit 55 per cent peat.

Table 5. Experiment 3. Effect of propagation regime and medium on rooting of Sitka spruce cuttings. (For details of regime codes see text.)

Location	Regime	G100		G75 P25		G50 P50		G25 P75		P100	
		%	RS	%	RS	%	RS	%	RS	%	RS
Newton	N	99	4.6	100	5.2	100	5.7	100	5.2	99	5.0
Banff and Buchan	W	97	4.8	99	5.6	99	6.1	98	5.8	85	5.3
	L	81	3.4	97	4.0	93	4.2	92	3.8	69	3.4
	C	76	3.6	95	5.3	93	5.6	94	5.5	68	5.8

Medium is grit (G) and peat (P) in percentage proportions by volume.

DISCUSSION

Good rooting performance with Sitka spruce cuttings can be obtained in a wide range of propagation media. However, the major effect of the mixtures noted in Experiment 1 suggests that not all products will be equally suited for use in rooting media. For example, an additive model was fitted ($p<0.01$) to the data from Experiment 1 to predict the rooting percentage if each component were used on its own. This gave theoretical rooting percentages after 20 weeks of 96, 94, 89 and 100 per cent for cuttings inserted in pure peat, pure grit, pure sand and pure bark, respectively. Thus, fine sand would seem to be undesirable for use in a propagation medium.

The positive relationship noted in Table 2 between percentage macropore space and rooting performance suggests that this measurement could be used to identify media prone to waterlogging because of poor drainage. Media of less than 15 per cent macropore space would be rejected. However, as noted by Loach (9), such measurements are an imperfect guide to the suitability of a medium for use with other species in different houses or at different times of year.

Experiment 3 emphasises the influence of the propagation system upon the choice of medium. At Newton, under open mist, all the five media tested were equally satisfactory for rooting although subsequent root development was better in media with approximately 50 per cent peat. However, under the various regimes at

Banff and Buchan, media with at least 25 per cent peat were desirable for rooting, particularly in the absence of base heat. This was because cuttings in pure grit tended to dry out, while cuttings in pure peat performed poorly presumably because of poor aeration, particularly following watering. The high rooting percentages in the better L and C treatments are interesting since they do not fully agree with Grange and Loach's (2) suggestion that conifers do not root well under enclosed polythene. This discrepancy may reglect climatic variations between Littlehampton in northern England where their studies were carried out and the more northerly position of our work on the Morayshire coast. For instance, interpreting data from max-min thermometers placed among the cuttings in our experiment suggests that average air temperatures at Newton and at Banff and Buchan were some 5°C lower than in the Littlehampton work.

There is no single "ideal" medium for propagating Sitka spruce. Providing the medium gives adequate support, drainage, and aeration, the propagator has a wide range of mixtures at his disposal and his choice is as likely to be dictated by cost as by cultural factors. Although we have noted that different media produce variations in root morphology, especially in the fineness of the root systems [see also Copes, (1)], these differences have never influenced subsequent performance of the cuttings when lined out into the nursery.

Experiment 2 shows how the nutrient regime given to a stock or mother plant before cutting collection can influence subsequent rooting performance. Thus cuttings given a high nitrogen (SN) or high general fertiliser regime (SB2) show poorer rooting than those given a lower balanced regime (SB1). More importantly, first cycle cuttings performed better than most second cycle cuttings apart from treatment SB1. Were it not for the latter, there would be a danger of ascribing these results to a difference in maturation state rather than to feeding regime. Similar effects of fertiliser regimes have been reported by Kleinschmit (6) for Norway spruce. Leakey (7) has also reported how adjusting fertiliser regimes improved rooting in cuttings from basal shoots of obeche (*Triplochiton scleroxylon*). Our results might be attributed to differences in nitrogen: carbohydrate ratios since these are considered to affect rooting (e.g. Hartmann and Kester, 1983, p. 259). Unfortunately, detailed foliar and carbohydrate analysis does not reflect striking treatment differences, particularly between second cycle cuttings.

CONCLUSIONS AND FUTURE DEVELOPMENT

These experiments were essentially empirical and aspects of climate during rooting and physiological processes in the cutting were mostly unrecorded. However, the high rooting percentages obtained in different years are encouraging, particularly in view of current commercial expansion in the vegetative propagation of genetically improved Sitka spruce. It is clear that cuttings can be rooted under a range of systems and in a variety of media. In addition, correct nutrition and manipulation of the mother plants to maintain cutting quality appear as important as the propagation system used. Results since 1982 indicate that Sitka spruce rooted cuttings can be produced in the type of facility described in Table 1 at approximately twice the cost of conventional transplants.

Could fogging systems replace mist for propagating forest conifers, now they are now more competitive in price? Shinn (15) has already described successful use of fogging with Western hemlock (*Tsuga heterophylla*) although rooting percentages are not high. We think that fogging will be of increasing interest for two reasons. Firstly, John and Mason (5) report that successful weaning of micropropagated spruce requires stable, high humidity environments. Humidity under open mist fluctuates too much for satisfactory weaning whereas fogging systems should provide conditions much closer to needed requirements. With Sitka spruce, commercial systems integrating micropropagation with stem cuttings may be operational by the end of the 20th century. Secondly, despite the high rooting being obtained with stem cuttings under open mist, nutrient status of the material is impaired during rooting and use of fogging might maintain the nutrient status better and possibly enhance the speed of rooting. However, the good results being obtained under open mist at the present time and the fact that nurserymen are propagating a relatively low-cost product, suggest that it would be premature for commercial growers to try fogging on a large scale with Sitka spruce until further results are to hand.

Acknowledgements. The experiments described in this paper owe much to the initial inspiration of Paul Biggin. Charles Blackwood, Allan Green, Graham Menzies, Mike Hollingsworth, and Jim Davidson all assisted in various ways. Robin Currie and staff at Banff and Buchan Nurseries were of considerable help with Experiment 3. Ian White provided statistical advice and analysis and Allan John commented on the draft.

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FOGGING IN TUNNELS

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Ellis Brothers is a slowly expanding young nursery and until the I.P.P.S. French trip in 1983, where we first saw fogging units being used, we were without a modern propagating unit. We need to propagate a wide range of subjects and realised that fog was the solution.

In the spring of 1984, with the help of MacPenny we installed a compressed air and water fogging system in a single 4.2 × 20 metre polythene tunnel. We have since expanded, and now have a fog system in three tunnels.

The original cost of the whole fog unit seemed at the time to be very expensive at £1,100 so the choice of structure had to be cheap, hence the tunnels. The tunnels in fact are double clad for energy saving and winter protection, and they are as well-built as possible with tightly fitting, fog proof, doors. The air to inflate the tunnel skins comes from a small fan situated in the building where the cuttings are made. This means that warm dry air from the working area is used, thus giving greater frost protection during the winter.

The two tunnels which are mainly used for rooting cuttings have basal heat in only half the floor area. This was originally done because of economy, but now we have found that due to high summer temperatures, rooting on the 'unheated end' is successful with easy subjects. This area has the added advantage of being a close at hand weaning area, in a similar environment.

In the MacPenny system, low pressure fog is produced by mixing compressed air at 70 p.s.i. with mains water at about 10 p.s.i. The sequence control and compressor are placed close to the tunnels for convenience and greatest pressure. Each 20 metre tunnel has two special fogging nozzles, one by the main door and one 15 metres away facing the other, this generally means that there is less fog at the far end, for weaning or working.

Most nurseries' fogging units have a humidistat incorporated, but with more than one tunnel being fogged at one time, this is impractical. To overcome the problem that English weather gives us while the cuttings root, the amount of fog needed during the day is constantly assessed and altered manually. During the night and at weekends the amount of fog needed is estimated, and the unit is programmed, with the aid of a time clock.

This small propagating unit is quite capable of producing 50,000 rooted cuttings at any time using the same area up to three times in a year. This is ample for the requirements of the nursery. However, we have been direct sticking more and more, and now about 30 per cent of our production is rooted in pots. Fog lends itself to this system very readily.

The fogging system we use is a closed system, indicating that we very rarely ventilate even in the brightest summer days. The high temperature means we must maintain very high (up to 99 per cent) humidity. We can achieve this easily. Moisture in the air remains in suspension for some time, depending on the brightness of the sun, but on the average, 5 to 8 minutes. The droplet size can be altered (it is usually about 10 microns) by increasing the air: water ratio in the fog mixture; this makes the fog wetter or drier.

Fog in tunnels creates a very humid environment, with high air temperatures of up to 40°C which we consider ideal conditions for rooting deciduous and broad-leaved evergreen shrubs. Obviously during the duller winter months there is lower air temperature and humidity, good conditions for rooting conifer and firmer broad-leaved cuttings. In addition to rooting cuttings during January and February, our limited seedling production and bench grafts are also subjected to fogging.

Bench grafting fills our propagating time in February and all the grafts are boxed up and placed in the fog tunnels—*Prunus, Malus, Robinia, Cytisus* and *Acer* all have the same treatment. The grafts are callused and allowed to break bud, after which they can be potted. About 90 to 100 per cent take can be expected with most cultivars.

Cuttings of some subjects, such as *Weigela, Forsythia, Fuchsia, Potentilla,* and other deciduous flowering shrubs root in 10 to 14 days. Generally speaking, softness is not a problem with rooting—if the cutting does not wilt, then it usually roots. Quickly-rooted easily-potted subjects are still inserted into trays of 50 per cent sharp 2mm grit and 50 per cent medium grade moss peat. More difficult to root subjects are direct stuck in pots either singly, double, or treble, in a medium of 20 per cent Cambark 100 and our liner compost which is nursery mixed. We find difficult-to-root plants usually do not tolerate root disturbance at the first potting, and if multiple stuck have a greater chance of survival.

Plants such as *Cotinus, Garrya, Acer palmatum, Photinia,* and *Convolvulus cneorum* do well under foggy conditions. Direct sticking of cuttings in our fog tunnels gives us greater evenness and uniformly of rooting, resulting in a better quality liner produced quickly, especially advantageous for cultivars where propagation speed is essential. Rooting grey-leaved subjects such as *Santolina, Senecio,* and *Helichrysum,* poses no problem, although weaning soon after rooting helps quick establishment.

As two or three nozzles produce enough humidity for rooting, in the future we hope to direct stick a tunnel of cuttings, and move the nozzles into the next tunnel and repeat the process. This should overcome the handling of so many rooted cuttings in pots, ultimately rooting in their two or three litre saleable pots. This seems only possible in the warmer months when bottom heat is not necessary.

Algal growth is not a problem with our unit, either on the polythene or paths. However, heavy shading is important to reduce the brightest sun. Having a fairly heavy shade, high temperatures, and high humidity we have encountered few problems of weaning-off cuttings before they are potted, however a good watering-in is important.

Fogging in tunnels is a very adaptable system when using variable amounts of fog throughout the year. We can root our cuttings, callus grafts, and germinate seeds as well as rooting conifers and weaning micropropagated material. We find the equipment easy to manage and problem-free.

THE SPECIFICATIONS FOR NEO PLANTS' NEW PROPAGATION UNIT

MARTIN HILL[1]

Neo Plants Ltd, Freckleton, Lancashire

INTRODUCTION

This paper describes how the specification for Neo Plants' new propagating house was drawn up. Decisions have to be influenced by existing circumstances, so while the ideal would be a bare field site and unlimited finances, few small companies would be so fortunate.

Neo Plants needed to expand its facilities in 1983 and bought a typical west Lancashire tomato nursery at Freckleton. It consisted of a 6ha site with a large bungalow, 1ha of venlo glass and two large sheds. Both laboratories and offices were housed in the bungalow and the nursery had good growing facilities which could be adapted into weaning and growing houses.

THE FIRST WEANING UNIT

Four years ago weaning micropropagated plants was a new science, especially for Neo Plants. Initially, only part of the available growing area was needed.

A weaning unit was set up in an existing 1000 sqm house, using three bays of the seven bays. Flexiheat electric underfloor bed heating was installed. Air heating was piped from a small package boiler and a fixed thermal/shade screen of woven polypropylene material and a MacPenny fogging system were installed. The weaning area

[1] Nursery Manager

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was separated from the rest of the house by a polythene partition.

Various modifications became necessary. The number of fogging nozzles had to be increased. Improved partitions were needed to maintain humidity and to seal up all gaps and holes which seriously affected the weaning of the plants. Doorways also caused a problem.

The remaining four bays of the glasshouse were used as a hardening off/growing area for early production which required heat. The remainder of the nursery was cold houses which could not be used for weaning before April.

EXPANSION

At the beginning of 1986, Neo Plants proposed to increase production from under one million plants per year to three million for the 1987 season. Extra facilities would be needed to accommodate this increase in production. The weaning/fogging area needed to be extended and the cold houses needed frost protection. Additional space was necessary for pricking out, tray filling, compost mixing, etc. and a better method of moving plants around the nursery needed consideration.

Proposal 1: To expand existing house. The weaning unit was set up so it could be expanded by using the whole 1000 sqm of the house. This, however, was discounted for the following reasons:

1. The pipe layout was not suitable, there being no perimeter heating, the main pipes were in trenches, the heating loops too low.

2. The boiler was in an unsuitable position and would have to be moved.

3. The vent system was inadequate, in fact non-existent above the screen because the house was too low.

4. Electric soil heating is too expensive for such a large area.

5. The bed layout resulted in poor use of space, over one-third being non-productive. (1 metre path every 3.2 metre bay)

6. There was no work area available for pricking out, tray filling, etc. within the area.

7. The fog system compressor was too small.

8. The house was on a slope and fog drifted to one end.

Proposal 2: To convert one of the other houses. A specification was drawn up and quotations obtained to convert a neighbouring house into a weaning unit, and build a work area and mixing extension. The cost worked out to be far more than we had anticipated. Also, we would lose a growing house needed for the extra production. The capital cost would be unjustified for what would end up as a compromise at best. We decided to increase the budget to build a new house to our "ideal" specifications based on experiences to date.

Proposal 3: To build a new house. We decided to build on a field at one end of the nursery, adjacent to an existing glasshouse. Here there would be access from the back road; services of water and electricity were available at the old propagation house and oil for heating could be piped easily from the bulk tank. A weaning house here would reverse the whole nursery causing the weaned plants to be nearer the nursery entrance when ready for dispatch.

An area adjacent to the new house, which had been used as a propagation house when the nursery was a market garden, and which had a concrete floor, would be converted into a work area for mixing, tray filling, and pricking out. This would be linked to the new house by a small extension to be used for boilers and controls etc., thus avoiding taking up propagation space with them.

By linking the house in this way we created a unit of nearly 0.75 ha under cover from the new weaning house, boiler house, work area, and four existing growing houses along a central corridor. Access would be via the corridor for pedestrians and by the back roadway for vehicles.

THE HOUSE AND ITS ENVIRONMENT

Up until the time the plants leave the growth rooms, they have been held at temperatures ranging from 18° to 25°C. It is necessary to provide a compatible temperature for the plants when they are pricked out, between 16° and 18°C minimum day temperature. To encourage rooting, base heating would be required at about 20°C. This also would provide the right microclimate at plant level via the moist sand and compost. Electricity would be too expensive to heat such a large area, so a low temperature hot water system beneath sand beds was chosen. The air heating would be provided by 51mm pipes suspended from the trusses and additional pipes around the perimeter.

Two boilers would be required, of 60 per cent total capacity each, to cover for break downs.

Light. The growth rooms have given the plants a regular daylength of 16 to 18 hrs every 24 hrs. It would be necessary to ensure that plants leaving these long days do not suffer when daylength is reduced, so night break lighting would be required.

Shade. Too bright an environment would cause losses from scorch. Shade also prevents the temperature rising too high, so a system of screens would be required. A mobile screen in the roof acts as a shade screen during the bright days and a thermal screen at night. Side screens are primarily for shade but do give added insulation at night. The material chosen was LS15 to give 50 per cent shade.

Humidity. Plants growing in culture are in sealed tubs. The relative humidity inside these tubs is in the range of 95 to 100 per cent. This high humidity causes the stomata in the leaves to be permanently open and they have not started to function normally at this stage. Also the cuticle on the leaves is not formed or is incomplete. If such a plant was to be pricked-out directly from culture into a dry atmosphere, it would wilt and scorch. It is, therefore, important to provide a fogging system to maintain a high humidity which reduces the transpiration rate to a minimum during the first few days or weeks of weaning into soilless composts. The fogging system must maintain a satisfactory atmosphere of 85 to 95 per cent RH but at the same time not cause any wet areas under nozzles. The systems considered were MacPenny, D.G.T. and Climatic Controls.

Cooling. During humidification in periods of normal temperatures, 18° to 28°C, the foliage should remain as dry as possible. However, when the temperatures start to rise higher, then a cooling system provided by a very fine jet of water for a few seconds is very useful, so long as the plants do not remain wet for long periods. One such system seen in Holland, manufactured by S.K.V. uses a water pressure of 30 atmospheres and could be controlled from 1 second to 59 second bursts.

Ventilation. Some ventilation would be needed when it becomes too hot. It is limited to the leeward side only, and in most cases that is all that is needed. Automatic vents would be needed on both sides of the ridge. A fixed screen would be required to maintain the humidity in the glasshouse growing area while the vents are open. It should be as light as possible so as not to reduce the light penetration in winter. It was for this reason we chose the polyester cloth L.S.10 which gives a 22 per cent shade and 40 to 45 per cent energy saving.

Insulation. To maintain an even relative humidity throughout the house, it must be well insulated. A cold draught would soon cause plants to wilt and die. This was very noticeable in our existing fog house which was far from perfect due to poor partitions and doorways. Double glazed sides and gables would be required, to reducing draughts in addition to saving energy.

Access. Good access doors are necessary and, once inside, the movement over the house should not be impeded by fixed equipment such as heating pipes. It was, therefore, decided that all heating pipes should be overhead and around the perimeter. No pipes should be in trenches. The mains supplying the base heating should not restrict movement across the house—hence they were to be fed from the far end via mains down each side and not near the header path.

Computer Control. A computer controlled environment, integrating air heating, base heating, humidity, ventilation, screens, and lights would be required and, in addition, a means of recording this information for future reference.

The Glasshouse. Taking all these factors into consideration, glasshouse manufacturers were contacted to see what types of glasshouses were available. The standard Venlo, double and triple Venlo, and the single span houses of 6 to 8m wide were considered. A house which would provide as clear a floor area as possible, with the minimum number of paths, would be ideal. It would be essential to make use of as much of the heated floor as possible but at the same time to leave access for plant movement. The standard 3.2m wide Venlo was far too restricted. Our existing fogging house of this type had 45 per cent of its floor area unproductive due to pathways down each bay and header paths at each end.

The triple venlo was also dropped because the area chosen for the new house was only wide enough for eight standard 3.2m bays and nine would be required to accommodate three triple bays.

Quotations for double Venlo houses of 6.4m and the single span houses of between 6 and 7m were sought.

DRAWING OF A SPECIFICATION

Advice was sought from various glasshouse manufacturers and other interested parties. Visits were made to other nurseries to look at their houses and equipment and the owners were asked if they were satisfied with their installations. If they had had more than one make of house, or more than one contractor to install the heating, etc., why did they change? Trips were made abroad to Dutch glasshouse manufacturers, irrigation companies, and nurseries.

One of the major difficulties was that there were very few glasshouses with fogging systems, especially a single unit in the region of 1000 sqm. In addition, most growers did not use their unit for weaning micropropagated material and so they ran the system in a different manner to the way we would need to use it.

By July 1986 a specification was drawn up to cover the glasshouse, heating, screens, and fogging required. This was sent to 10 companies. We gave plenty of detail of our requirements, under main headings such as Dimensions, Heights, Vents, Doors, Paths, Storm bracing, etc. followed by short descriptions or measurements required. The more detail given at this stage the less likelihood of any errors or misunderstandings by the contractors.

EVALUATION OF THE QUOTATION

Seven quotations were received, five from manufacturers of the double Venlo (Bridge, Wilco, HOK, Simpsons and DACE), and two for single span houses (Cambridge and Robinson). To give complete flexibility, we also received quotations from:

Climatic Controls for their fogging system, screens, and computer; MacPenny for the fogging system; Victor Automation Systems for their computer; Van Vliet for their computer; Southern Heat and Controls for the heating, fogging, and computer.

When all the quotations were received, a master sheet was drawn up to compare one company with another. Most quotations gave a breakdown of the cost for each section or part of the quote, so aiding comparisons. In comparing prices, care must be taken to ensure that all requirements have been covered.

Glasshouse comparisons. The single span houses were more expensive than the double Venlo. They were more or less the same size so it was felt for this factor alone they gave no advantage.

Both Robinsons and Cambridge houses have good continuous rack and pinion vent systems and the higher ridge would provide a large buffer of air above the screen which can be an advantage to equalise extremes in temperature below the screen at plant level, especially important during very hot days and very cold nights.

The installation of screens in single span houses is not quite as straightforward as in the double Venlo where it is fitted horizontally to the roof truss. The truss in the single span houses have side braces which would protrude below the screen or involve a more complicated screen support system which, in our view, did not look as good as the horizontal screen fitted to the lattice truss of the double Venlo.

Comparison of heating systems. The construction of the heated sand beds differed widely among companies. All companies used buried PE plastic tube but the major variation was in the spacing of the tubes from 0.8m apart for Wilco and DACE, 0.6m for HOK and 0.2 m for Bridge, Simpson, and Southern Heat.

The first three companies were using pipe spacing that is popular in continental Europe for under soil heating where the pipes are buried to a depth of about 0.4 to 0.5 m, unsuitable for a sand propagation bed. Also the companies with wider spacing did not want to construct the sand beds. They would leave the plastic pipe etc. for us to lay and connect up when the beds were complete.

Southern Heat and Controls Ltd covered the whole aspect of sand bed construction in their quotation, from 50mm depth of pea gravel on the base for drainage followed by 25mm polystyrene sheets covered with polythene. On top of this the PE pipes are laid and pegged down at 200mm spacing followed by the 100mm sharp sand cover.

THE FINAL CONTRACT

The ideal quotation to accept would be from a single contractor who can do all the work from the glasshouse construction to the final electrical connections. This simplifies matters considerably because if there is a delay in one part of a contract then there is a knock-on effect which upsets the plans of the other contractor if the contract is split. On the other hand, one should not only look at full contracts but leave options open, contacting companies supplying the computer control, fogging systems, heating and screens separately. In the end we decided to split.

One of the visits made earlier had been to Findons Nurseries at Stratford Upon Avon where we were shown an installation nearing completion by Roger Saint of Southern Heat and Control Ltd. This was a propagation house built by Bridge and heated by Southern Heat. It consisted of perimeter and overhead heating pipes and a heated floor similar to the one we required except that it was concreted after the pipes had been laid. We were also shown the D G T fogging system in another house.

It was very impressive and certainly appeared to provide the correct atmosphere. There was no fall-out onto the plants, which was a problem with some systems we had seen. The cost was also considerably less. Therefore we offered the contract for heating, both piped and soil, the sand bed construction, the boilers and related equipment, together with the computer and controls to Southern Heat and Control of Spalding.

We considered that this company would provide the best system to suit our needs and they were used to the construction of heated sand beds. They had also worked closely with the D G T fogging system and computer control, which we considered would give us the best fogging system we had seen, linked with a very good computer.

The glasshouse was to be from one of the double Venlo companies and we had a short list of four—Bridge, DACE, HOK, and Wilco. The house we were to build was on an exposed site and was to be higher than our existing houses, so it was felt that the construction must comply with Dutch building standards. A cheaper quotation was therefore dropped as it was too weak, the double venlo steel specification being identical to the single. There was not a lot to choose among the others, they all seemed to provide what was wanted, with slight variations. Bridge's quotation, together with Southern Heat, satisfied our requirements but they could not guarantee completion by the end of the year due to their other commitments.

The final decision was made more by the need to start than anything else. We wanted completion by the end of December. The decision was made to have the Van Der Hoeven house supplied by DACE through Mr. P. Bishop of Commercial Greenhouse Sales, who is now acting as agent for Van Der Hoeven direct. They were also to supply the thermal screen.

IMPROVEMENTS AND ALTERATIONS

Although we have the best structure and equipment circumstances allowed at the time, after nine month's use, the need for some modifications and improvements has become apparent, which could be considered in any future expansion:

1. The possibility of a further 0.5m in height to ensure adequate

space for the equipment in the roof-fogging, heating, screens, and lights.

2. A slightly thicker mobile screen material of LS16 to give a 60 per cent shade. This is most important to keep the house cool in very hot weather.

3. The possibility of roll-up side screens, rather than one which moves with the roof, to give more flexibility.

4. The inclusion of a secondary cooling system in addition to the fogging system for use when temperatures reach 30°C. This would take the form of very high pressure spray lines in the region of 30 atmospheres. This was considered for our present house but was dropped because of cost.

5. Control of the water and air temperature used in the fogging system is non-existent. A means of cooling these in summer would be a great advantage in keeping the temperature down.

CONCLUSIONS

Allow plenty of time for building. Ensure that the site is levelled well in advance of the starting date, to give time for the land to settle and give a reasonable working surface from which to build. Failure to do this may, in a wet season, result in a mud bath. The removal of between 150 to 200 tons of mud from inside a glasshouse, with shovels and dumper truck, for two weeks in December, is something I am not likely to forget.

ULTRASONIC FOGGING SYSTEM—SONICORE NOZZLES

J. DONOVAN

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To obtain best results from a fogging system each water droplet must be of the correct size. The smaller the droplet the larger the number present from a given volume of water. It is the greater number of very small water droplets that gives optimum coverage and distribution of the fog.

Fog works because the small droplets, with very little mass, stay in suspension drifting with any air movement until they evaporate. Large water droplets must not be formed as these will fall in the immediate area of the nozzle causing overwetting.

Sonicore atomising nozzles can produce much smaller droplets than conventional nozzles. The nozzles are air-driven "acoustic space for the equipment in the roof-fogging, heating, screens, and lights.

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Sonicore atomising nozzles can produce much smaller droplets than conventional nozzles. The nozzles are air-driven "acoustic oscillators" which break up water into tiny droplets by passing it through a field of high frequency sound waves. The air expands through a convergent/divergent section (rather like a whistle) into a resonator cap where it is reflected back to complement and amplify the primary shock wave. The result is an intense field of sonic energy, a shock wave, focussed between the nozzle body and the resonator cap.

The energy within the shock wave, generated by high pressure air, shears into droplets any water pumped into it. Air from the nozzle that happens to by-pass the resonator carries the atomised droplets downstream in a soft plume-shaped spray. The droplets have a low mass and low forward velocity with low impingement characteristics. Fine atomisation ensures uniform distribution of the moisture with minimum overspray and waste.

Large liquid ports in the nozzle prevent clogging or malfunction. Low water pressures considerably reduce wear, maintenance, and performance deterioration with continuous use. One major advantage of the nozzle is the ability to provide a consistent quality of atomisation over a wide flow range. Turn down ratios of 50 to 1 are possible.

Sonicore nozzles are available with flow ranges from 0.4 to 4,550 litres per hour but there are only two sizes used in horticulture—the 035H with a flow range of 0.4 to 8 litres per hour and the size 052H with a flow range of 1.0 to 20 litres per hour. With the high humidities required for plant propagation you will require one nozzle per 150 m^3 of room volume.

Sonicore nozzles can be operated in gangs from large air and water manifolds, but for fine control and an even moisture distribution it is much better if each nozzle has its own air and water regulators. The most popular arrangement is the type 5301B atomiser station where on/off valves and pressure regulators with pressure gauges are mounted with the nozzle in a neat package. The atomiser can be remotely switched from either hand, timer, or humidistat controller.

Alternatively, complete systems, with all the valves, gauges, and switches mounted in a master control panel with air and water pipes to each nozzle, are available.

The Sonicore nozzle uses a resonator cup supported on two wire legs to reflect the air stream shockwave escaping from the main body of the nozzle. If the resonator cup is bent out of alignment or broken off it can easily be replaced. In an emergency the cup can be re-aligned by passing the nearest sized drill through the nozzle and lining the cup up with the drill.

AN INTRODUCTION TO THE MICRON 5 FOG SYSTEM

J. R. DENTON

Fordingbridge Engineering Ltd, Arundel, Sussex

INTRODUCTION

The use of "fog" or humidification systems is becoming increasingly popular for propagation in the UK and is producing encouraging results.

The objective is to raise the humidity of the growing environment. This is done by producing water droplets that are sufficiently small to remain in suspension in the air long enough for them to evaporate and increase the relative humidity.

There are two basic forms of fog system, the air and water system which requires a compressor, and the high pressure water-only system, the Micron 5 Fog system being the latter type.

How 'Fog' is Produced. In high pressure water-only fog systems the droplets are produced by forcing water at high pressure through a specially designed nozzle.

The stainless steel nozzle used in the 'Micron 5' fog system operates by channelling the incoming water through a small orifice producing a fine jet of water. This is shattered on impact with an "anvil", positioned directly in the jet, creating a cone of fine water droplets.

The nozzle orifice is less than 0.03mm in diameter and, in order to prevent blockage, a ceramic filter is incorporated to remove any particles in the water supply.

Droplet Size Analysis. Fordingbridge Engineering and AFRC Engineering (formerly the National Institute of Agricultural Engineering), have performed research to determine the diameter of droplets produced at varying operating pressures by the nozzle used in the Micron 5 system.

Measurement of droplets size was done using a particle size analyser which operates by analysing the shadows cast by droplets passing through a laser beam.

The results are expressed as the percentage by volume of the number of droplets having a diameter less than 10 μm and as we expected, an increase in operating pressure resulted in a decrease in droplet size.

Increasing the pressure above 1000 psi leads to only small improvements in the resulting droplet size, so the recommended operating pressures of the Micron 5 Fog system is 1000 psi which produces droplets, 50 per cent of which have diameters less than 10 μm.

Design and Manufacture of the System. The pump pressure set basically provides water to the nozzle at sufficient pressure to produce the required atomisation.

Water from the mains is first filtered to remove particles down to 5 μm before entering a break tank from which it is then drawn into the pump and pumped into the lines via a flexible hydraulic hose. For most units the pump is driven by a 1 hp motor via a belt drive enabling 45 nozzles to be run off one unit; however larger units are available.

There are two basic safety features incorporated in the design. They include a float switch to prevent dry running of the pump and a pressure relief valve to prevent operating the unit above 1200 psi.

To prevent the nozzles dripping after a fog burst, a dump valve opens, discharging any excess water pressure back into the break tank.

The pump pressure sets and fog lines are assembled in the factory and are fully tested before dispatch.

Installation Design. When designing an installation it is the number of nozzles and their positioning within a greenhouse that is of most importance.

Each nozzle produces 5.8 l/hr at 1000 psi and it has been found that between 17 and 20 cu.m. should be served by one nozzle. This usually results in the spacing of the nozzles being between two and three meters and the spacing of the lines being around 3.5 m. However these are only guidelines, the final design depends on the type and size of structure involved.

It is recommended that, as far as possible, the propagating house be relatively draught free as even a mild amount of ventilation can result in excessive use of the fog system to increase the humidity of the incoming air.

The use of a screen above the propagating area is also recommended as this restricts air movement, thus maintaining the humidity. Many screen materials have been tried but surprisingly good results have been obtained using materials such as 'Agril' and 'Agronet'.

Experience is also beginning to show that placing the nozzles in a vertical position approximately 0.5m above the propagating bench is providing very good results.

Typical Results Using Fog. Mr. David Tristram, proprietor of Walberton Nurseries in Sussex, who was very much involved with the development of the Micron 5 Fog System, now has two systems, one of which has been installed for over a year.

Both systems are installed in rather old greenhouses approximately 7m wide by 20m long. The pump pressure sets are located at the top end of the structure with the fog lines running at approximately 0.6m above the ground down either side, the nozzles being angled at 45° towards the centre of the house.

The cuttings are propagated in trays without any base heat with the fog on a time-burst sequence only. Mr. Tristram feels at this stage that he is probably over-fogging, the humidity being in the region of 100 per cent most of the time. However, this has had no adverse effect on his cutting take; in fact, he reports significant increase in the take of deciduous azaleas to around 100 per cent, an increase of 25 per cent over his conventional mist propagation system. Clematis has also improved with a 15 per cent increase in take. He has also seen quicker rooting with plants such as spirea and dogwood, but is not sure of the advantages of using fog with conifers at this stage.

The improved rooting of so many plant cultivars under fog, has interested Mr. Tristram in moving toward direct sticking procedures next year, again without the use of base heat. He is also intending to purchase a further fog unit at the beginning of next year, to have three mobile units—the intention being to fill a particular house with cuttings, propagate, and wean off using the fog then move the fog on into the next house leaving the plants *in situ*. Mr. Tristram feels that direct sticking and reducing the handling of the cuttings will result in more economic production.

CONCLUSIONS

Since the introduction of the Micron 5 Fog System, nearly one year ago, it has received great interest from British growers, primarily for humidification control, but also for cooling and shading. Its practical attributes, including its ease of installation and operation, its low running costs, and even humidity distribution, have resulted in many systems being installed.

THERMABED—FAILURE THEN SUCCESS

CHRISTOPHER FAIRWEATHER

Aline Fairweather, Beaulieu, Hampshire, U.K.

With the increasing demand for rooted shrub cuttings and liners we decided in 1986 to double the heated space we had available for propagation.

Our first house was installed in 1979, and our first installation was a simple hot water system using alkathene pipe and a second-hand 120,000 B.T.U. boiler for which we paid only £10. This original system is still working well and we find it generally satisfactory. The main drawbacks are the considerable work involved with the installation. The other disadvantage we have noted over the years is the uneven temperature. There can be as much as five and sometimes 10 degrees drop, with the highest temperature near the boiler, dropping away at the farthest point.

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Early in 1986 we prepared a new site and erected a 12m by 21m aluminum glasshouse. Our original hot water system had generally worked well for us and running costs had compared very favourably with other possibilities. Electricity on this scale would be easy to install but very expensive to run; added to this our available electric supply was limited. We do not have mains gas available. Therefore, we again turned to oil as our source of heat. The price of second-hand boilers had moved up a bit over the years but once again we managed to find another 120,000 BTU model, this time at £40.

Finally, we had to decide how we should move the hot water around this new house. To save time on installation we decided on the Thermabed system as being the best for our needs. The polystyrene moulded units that carry the flexible water pipe come in standard sizes of 1.332m by 2.0m. We installed this new system on the floor of our new house. The ground was levelled and the Thermabed was laid on sand. With a concrete path down the centre of each six metre bay we formed four beds. To ensure a really flexible system we divided the four long beds in half and installed the necessary valves to divide the house in to eight separate heated units. The hot water from the boiler was pumped to a header main across the centre of the house. This we have found eliminated any variation of temperature.

Any failure on this system was perhaps our own fault. Overhead we incorporated an automatic mist system and we hoped that by covering the Thermabed with capillary matting this would prove satisfactory. In the early part of the year this worked well, but we did find the matting quite difficult to keep clean and, in addition the cuttings rooted into it. As the year progressed and temperature started to rise it became apparent that with more frequent mist the matting was holding too much moisture and the cuttings were too wet. This we quickly replaced with around five centimetres of well drained sand; since then we have had no further problems.

Over the past two seasons we have been very pleased with this system; using a Nobel sensor we aim to maintain a temperature of 21°C in the sand which gives us a consistent 15.5°C in the trays. We put the cuttings in large Dutch trays with well-drained mesh bases. Starting around March or April we use the mist. Over the winter months, about late October we turn off the mist and cover all the beds with light polythene resting on a framework that we made ourselves. This keeps the polythene five centimetres or so above the cuttings. During these months we remove the polythene each week and apply a variety of fungicides.

We believe that the Thermabed has given us an economical and sufficient system that certainly achieves all that we require.

GROWING RHODODENDRONS FROM TISSUE CULTURE

ANNA J. KNUTTEL AND LORI K. BENOIT

Knuttel Nursery, Inc.
East Windsor, Connecticut 06088

An accelerated growth program for growing tissue-cultured rhododendrons in heated greenhouses during the winter is one way to produce large quantities of small well-branched plants. This method of growing reduces the time needed to produce saleable plants. In 1985 Knuttel Nursery, Inc. implemented such an accelerated growth program that was based on work done by Jim Cross (1).

During the first year of this program, small rooted plantlets were potted in 3 in. cell packs and placed in trays. The trays were placed on pallets on the ground and lights were strung over them. Presently, all rooted cuttings are potted in 14×16×3½ in. trays and placed on 3 ft high benches. These trays retain water more evenly than the cell packs and the plants perform better in them.

The soil mix consists of two yd^3 softwood bark, 1 yd^3 each of sand, peat, and hardwood bark, to which is added dolomite lime, triple superphosphate, and Osmocote 18-6-12 (8 to 9 month formulation).

The plantlets are available in two sizes: a rooted cutting resembling a seedling and a 2 to 3 in. well-established liner. The cost of growing the rooted cutting to the size of the liner is less than the difference in price between the two sizes. There are also fewer growth problems if the plants are established in the new soil mix at the smaller stage.

The plants are put in a greenhouse heated to between 68 and 70°F by an oil-burning furnace which blows hot air through poly-vent tubing underneath the benches. The soil temperature is approximately 60 to 62°F. After the plants are actively growing, the air temperature is lowered to between 62 and 65°F.

Tall spindly rooted cuttings are potted deeper than usual. Up to one inch of shoot length can be planted below the soil level. Once the tissue-culture plants have been potted, standard management practices are followed. Irrigation needs are carefully monitored and a preventive spray program is followed. Most management time is spent pruning to produce full, multi-branched plants.

The plants become established in a month. They are fertilized with Peters 20-0-20 every ten days until mid-March, and then Peters 20-20-20 is used. Soluble salt levels are carefully monitored.

During the winter months the natural daylength is extended by lighting with clear incandescent 75 watt bulbs. These lights hang 2 ft above the plants and are 4 ft apart. At night the lights come on for 5 min every half hour (2). Jim Cross found that the benefits of artificial lighting were minimal (1). We are running experiments this year to assess the actual benefits of lighting.

In the winter of 1985, kerosene heaters were used to enrich the atmosphere with carbon dioxide. Last year this practice was discontinued with no significant difference in growth.

In May the large liners are potted into 1½ or 2 gal pots, and placed in the normal container production cycle. The plants are pruned once more in June. Many are saleable at the end of the season at a 10 to 15 in. size. Even though their growth cycle has been altered, these plants are winter hardy in northern Connecticut. The plants that have not been sold are potted into 3-gal containers the following spring. They are pruned in June and at the end of that growing season they are saleable 18-in. or larger two-year-old plants. A non-accelerated plant requires at least one more growing season to attain that size.

Before the start of the accelerated growth program, it cost 62% of the sale price to produce rhododendrons. Tissue culture plants grown through this program cost 46% of the sale price. Costs may further decrease as these growing techniques are refined.

There are some problems, however, associated with growing tissue-cultured plants. Certain rhododendron cultivars show variability. For example, 'Molly Fordham' grown from tissue-cultured plants exhibited 35% brooming while those grown from stem cuttings under the same conditions had no brooming. The 'Molly Fordham' that showed the brooming did not thrive. Other cultivars, such as rhododendron 'Aglo', displayed variation but appeared to grow out of it.

Tissue culture labs grow their plants under different conditions. Therefore, the same cultivars may vary in growth and performance depending on the source.

There are some cultivars that are difficult if not impossible for us to grow. Rhododendrons 'Bali', 'Nepal', and 'Golden Gala' exhibited extensive leaf-tip burn even though no fertilizer was applied. Adjacent to these plants were cultivars that thrived. Therefore, most cultivars are test grown in small quantities before they are put into large scale production.

A serious problem with some tissue culture sources is that the labs have inadvertently sold cultivars that were not true to name. Since tissue culture transplants do not resemble the mature plants, production time and money will be spent before the mistake is discovered. A nursery also may not have a ready market for the incorrect cultivars. In addition, if no one at the nursery is familiar with the mature plant a cultivar will be marketed under the wrong name. The frequency of these mistakes indicates that some tissue culture labs are not addressing this issue with enough concern. The grower is often left with the financial burden of this error.

Even with these problems, growing tissue-cultured rhododendrons in the accelerated growth program is worthwhile. It enables one to grow better quality plants more quickly and profitably.

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EFFECTS OF SPENT MUSHROOM COMPOST ON THE PRODUCTION OF GREENHOUSE-GROWN CROPS

JOSEPH DALLON, JR.

Ramapo College of New Jersey
Mahawah, New Jersey 07430

Abstract. Selected cultivars of *Chrysanthemum morifolium* and *Lilium longiflorum* were grown under greenhouse conditions in different ratios of spent compost, and in two commercial growing preparations, with either a 14-14-14 slow release fertilizer, or with a 20-20-20 water soluble nutrient solution. In all cultivars of both plant species, the most commercially desirable plants were produced in spent compost and Speedel in a 1:1 ratio. Plants with the highest bud count were also produced in this mix. The shortest plants were produced in spent compost alone, which exerted a growth retarding effect in all media and nutrient combinations. Nutrient treatments alone had no significant effects on flowering, root development, or bud count.

INTRODUCTION

The use of top soil as a growing medium component for greenhouse and container grown plants has declined. Contamination from herbicides, microorganisms, nematodes, and weed seeds, together with increasingly high cost factors have contributed significantly to this decline. At the same time, the use of commercially prepared growing mixes has risen sharply. These soilless materials have all the characteristics normally associated with a good growing mix. They are contaminant-free, light weight, have high air and water-holding capacity, and drain well. They are also comparatively inexpensive, particularly in consideration of labor and other cost factors associated with the preparation of soil-containing mixes.

The low weight factor associated with perlite, vermiculite, and sphagnum peat-containing commercial mixes is especially significant in minimizing cost when being shipped to distant markets.

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The low weight factor associated with perlite, vermiculite, and sphagnum peat-containing commercial mixes is especially significant in minimizing cost when being shipped to distant markets.

Thus, an important consideration for certain local markets is the availability of locally produced materials that could be used as a potting mix component. Materials such as bark, shells of various nuts, coconut husks, sawdust, and spent compost offer immediate or potential means of reducing production cost factors and possibly improving crop quality also. This work addresses the feasibility of using spent compost alone, or as an additive to media mixes for growing greenhouse crops.

Ready availability, nutrient content, and low cost are potential advantages of using spent compost as a growing mix component. These advantages could outweigh the disadvantages of high bulk, initial high water and salt content, lack of uniformity, and reduced structural qualities.

Successful production of selected floricultural crops in spent compost under greenhouse conditions has been reported, (2,5,6,7). The material consists of the remains of fungal mycelium, recycled hay from stable bedding, cotton seed hulls, poultry litter, gypsum, and horse manure.

Initially, upon completion of a mushroom crop, which requires approximately 12 weeks, the salt content of the compost is too high for immediate use. However, after 2 to 3 years of weathering, decomposition, and leaching certain floricultural crops have been found to respond favorably in spent compost as a growing medium (5).

The objective of this study is to further evaluate the feasibility and potential benefits of using spent compost as an additive to the growing medium of floricultural crops.

MATERIALS AND METHODS

Rooted cuttings of chrysanthemum cultivars, Luv, Tip, Surf, and Spirit, along with bulbs (10 in. and up) of Easter lily cultivars, Ace and Nellie White, were potted in five and six in. standard plastic pots, respectively, in the following media: Pro Mix Bx, spent compost, spent compost + Speedel 1:1, and spent compost + Speedel 2:1. Spent compost (S.C.) was obtained from a commercial mushroom grower in eastern Pennsylvania.

The plants were split into two blocks; one containing Osmocote (14-14-14) incorporated at a rate of 5 oz/ft^3. The other was fertilized with Peter's water soluble fertilizer (20-20-20) at 200 ppm nitrogen on a constant feed basis, and leached once per week. Each treatment consisted of three randomized replications of three plants each. Plants receiving Osmocote were watered on a regular basis as required.

The chrysanthemum experiments were initiated on 5 February, 1987, and at this time did not require shading. However, pre-forcing lighting and pinching were applied according to normal cultural procedures (4).

Prior to potting, Easter lilies were soaked in a fungicidal solution according to recommendation in Ball's Red Book (4). Plants were placed on raised benches pot-to-pot until the shoots reached a height of 10 to 12 cm. They were then moved to final spacing of four plants per 30.5 cm.

The growth retardant, A-Rest®, was applied to lilies as a spray to the point of run-off at concentrations of 62.5 and 125 ppm when they reached a height of 7.5 cm. Day/night temperatures were maintained at 22 and 17°F, respectively.

RESULTS

Chrysanthemums. These flowered uniformly in all media combinations. There were no significant differences in bud count due to media treatments, except in the cultivar Spirit (Fig. 1). Here the S.C. treatment resulted in fewer flowers than plants in S.C. + Speedel at both 1:1 and 2:1 levels. Spirit produced significantly fewer flowers in spent compost compared to the cultivar Luv, but not Tip or Surf. All other media combinations produced plants with insignificant differences in the number of flowers. Thus, with only one exception, spent compost was as suitable a growing medium as Pro Mix.

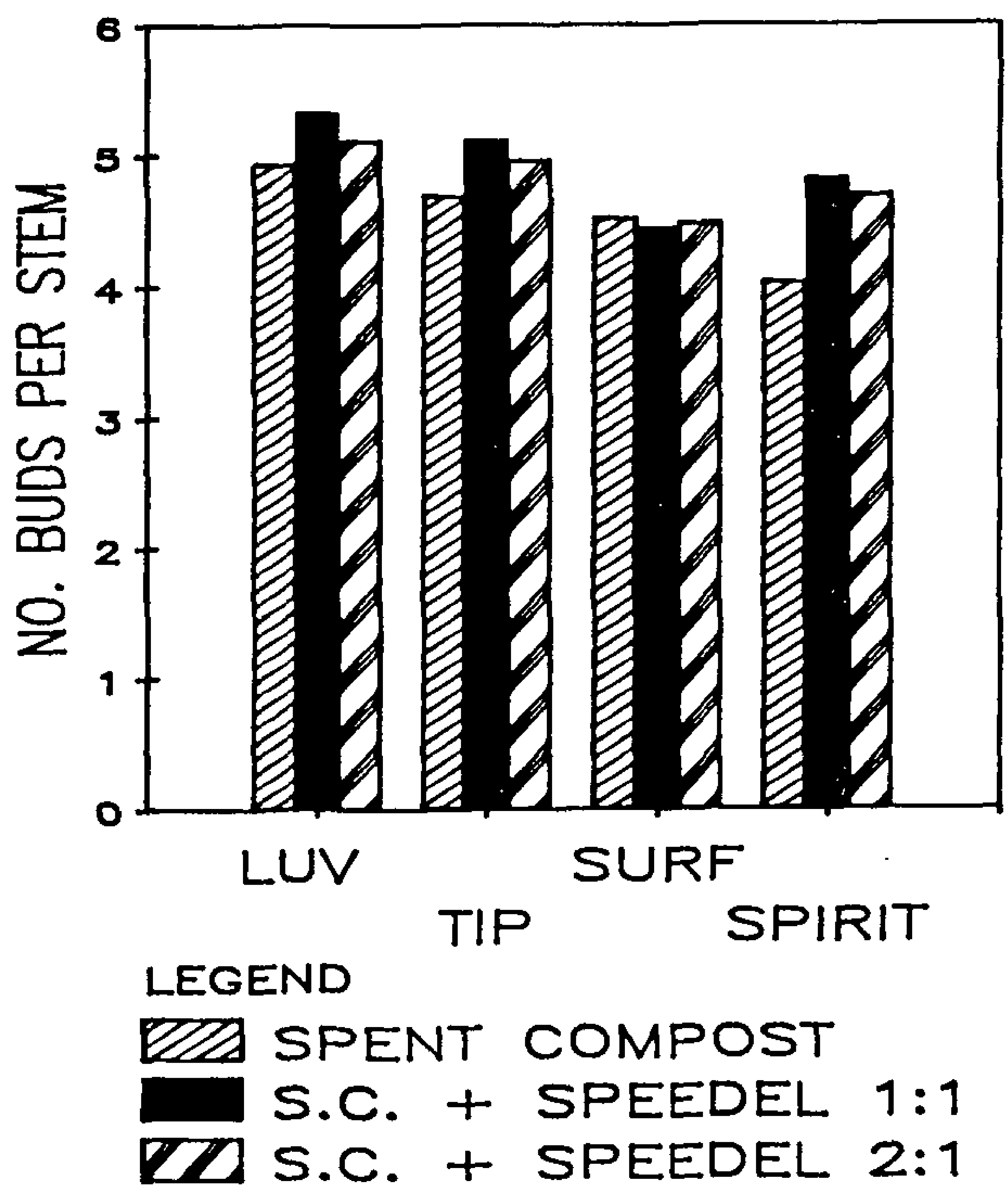

Figure 1. Effects of growing media on bud count in selected chrysanthemum cultivars.

The differences in spread due to media treatments were apparently genetically related. Luv was uniformly smaller in spread, ranging from 62 to 68 cm, while Tip, Surf, and Spirit all had a higher range.

The most significant difference in media treatments was observed in height. There were clear genetic differences. All cultivars grown in spent compost were significantly shorter than those grown in all other media (Fig. 2). Among the four cultivars grown in spent compost treatments, the retarding effect was greatest in Luv and Tip, compared to Surf and Spirit.

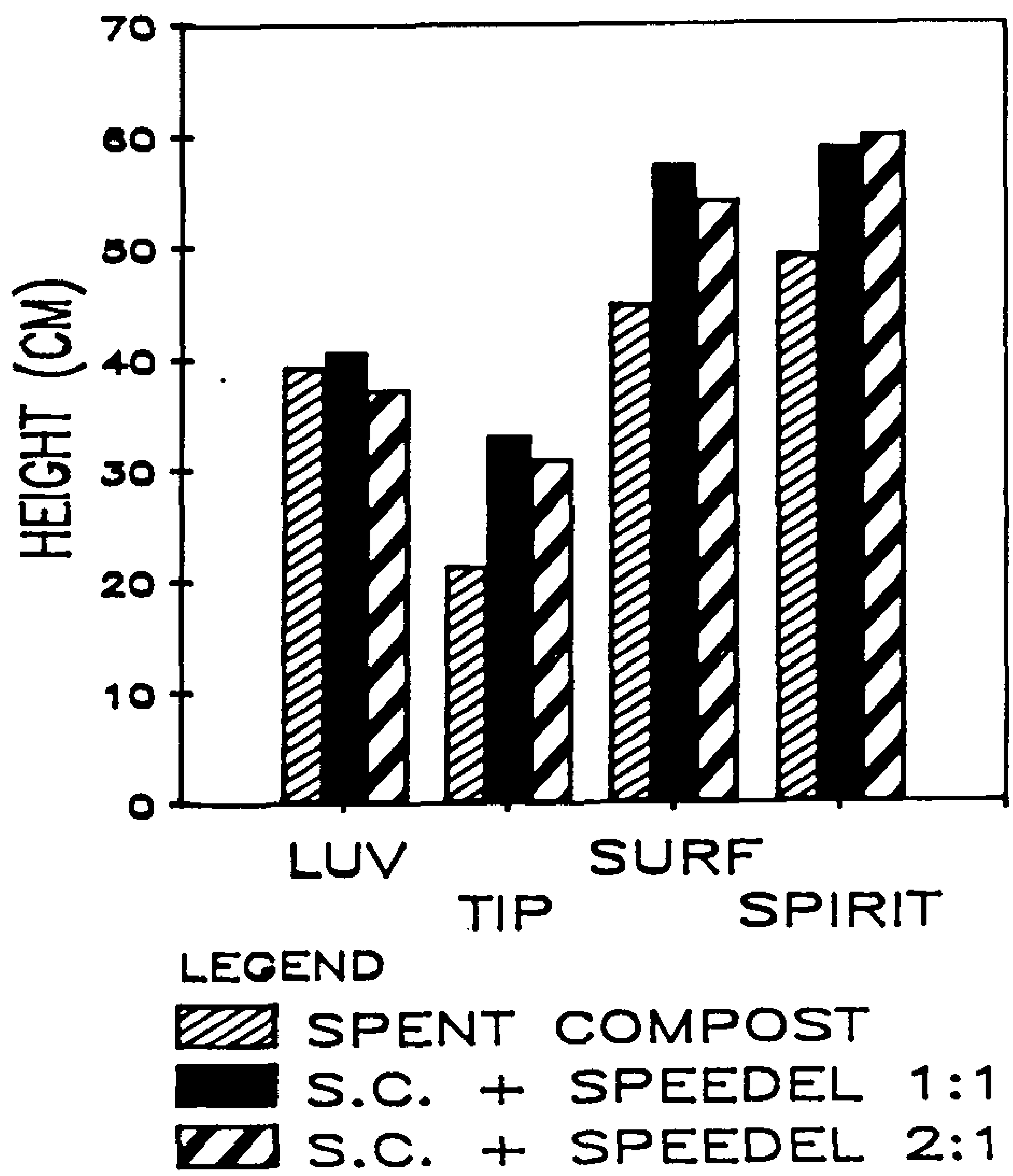

Figure 2. Effects of growing media on height in selected chrysanthemum cultivars.

Because of the high salt content in spent compost, roots were evaluated in each of the cultivars at maturity. Using a subjective system of 1 to 5 for evaluating root development (1 = poor, 5 = excellent), it was determined that the root systems of plants grown in spent compost was comparable to that of all other media, except in the cultivar, Spirit. Here the roots displayed a faded brown color that was uncharacteristic of normally healthy roots. This difference in root development was also reflected in the lower number of buds produced per stem in this cultivar. The condition is probably due to greater uptake of water by Spirit, thus leading to more rapid and frequent drying out, compared to the other cultivars.

Chemical analysis of the spent compost used in this study revealed an uncharacteristic profile compared to commercial and normally composted soils. This was especially so with respect to soluble salts and calcium. In addition, nitrate nitrogen, potassium, and magnesium levels were considerably higher than normal for freshly prepared greenhouse soils (Table 1).

There were no differences in cultivar response in any of the chrysanthemums tested due to fertilizer treatments.

Table 1. Spent compost nutrient analysis

Element	Nutrient level (PPM)
Macronutrients	
Nitrate nitrogen	213.00
Ammonium nitrogen	1.49
Phosphorus	3.18
Potassium	160.00
Calcium	554.00
Magnesium	62.00
Micronutrients	
Manganese	0.028
Iron	0.205
Copper	0.064
Boron	0.382
Molybdenum	0.089
Zinc	0.028
pH	7.53
Soluble salts (mmhos)	3.45

Easter lilies. The growth-retarding compound, A-Rest®, was used as a means of controlling height in the lily cultivars. Height reduction was proportional to the concentration applied, as illustrated in Figure 3.

More flowers were produced in Nellie White than in Ace, (Fig. 4). This was true both with and without A-Rest® applications. Neither treatment had any effects on the hastening of flowering in Easter lilies.

From these experiments it is clear that spent compost can be effectively used as a growing medium additive for some greenhouse-grown crops. It remains to be determined how uniform this medium might be when obtained from different mushroom growers, and what effects variability in uniformity might have on the growth and development of certain crops.

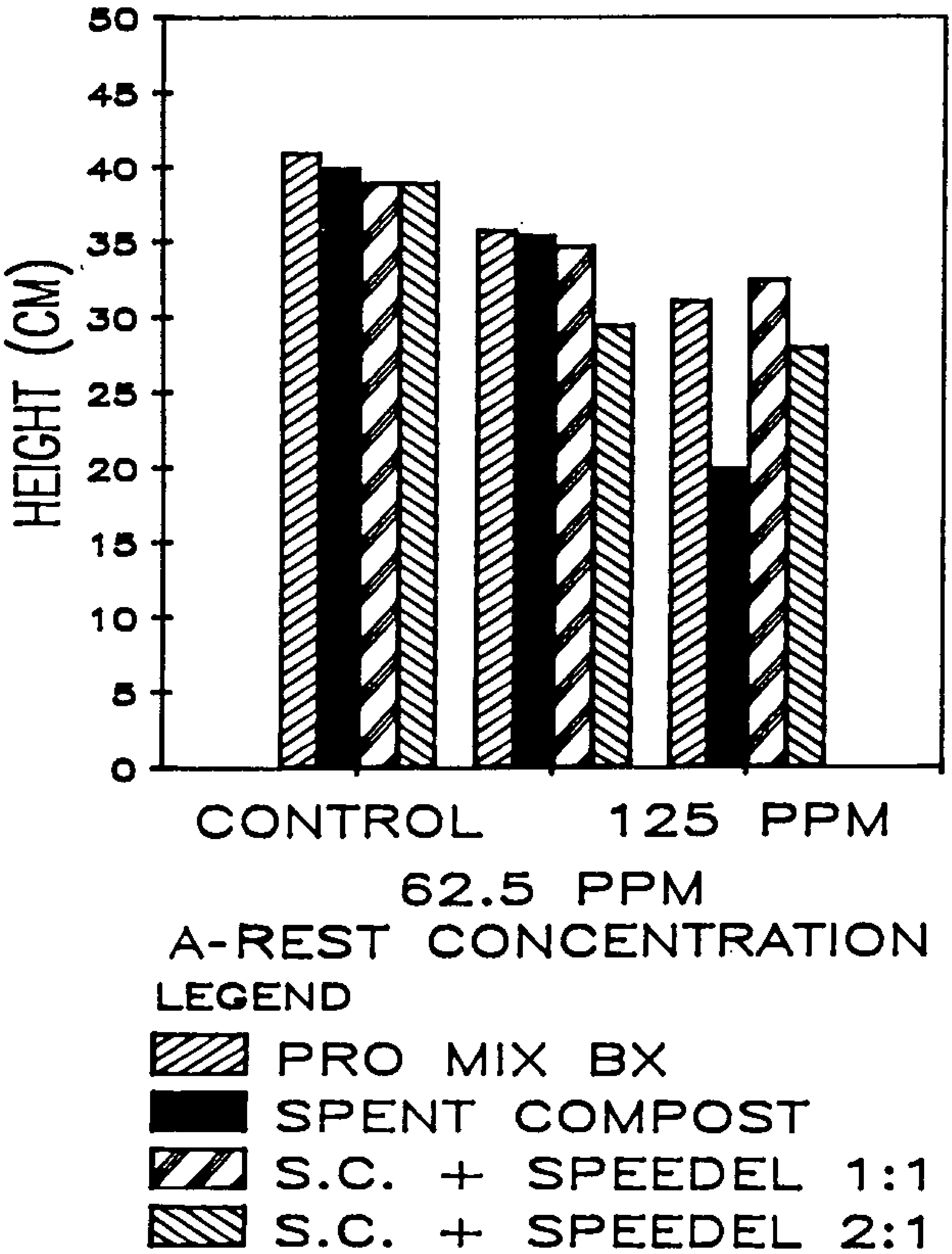

Figure 3. Effects of growing media and A-Rest on height in Easter lily cv. Ace.

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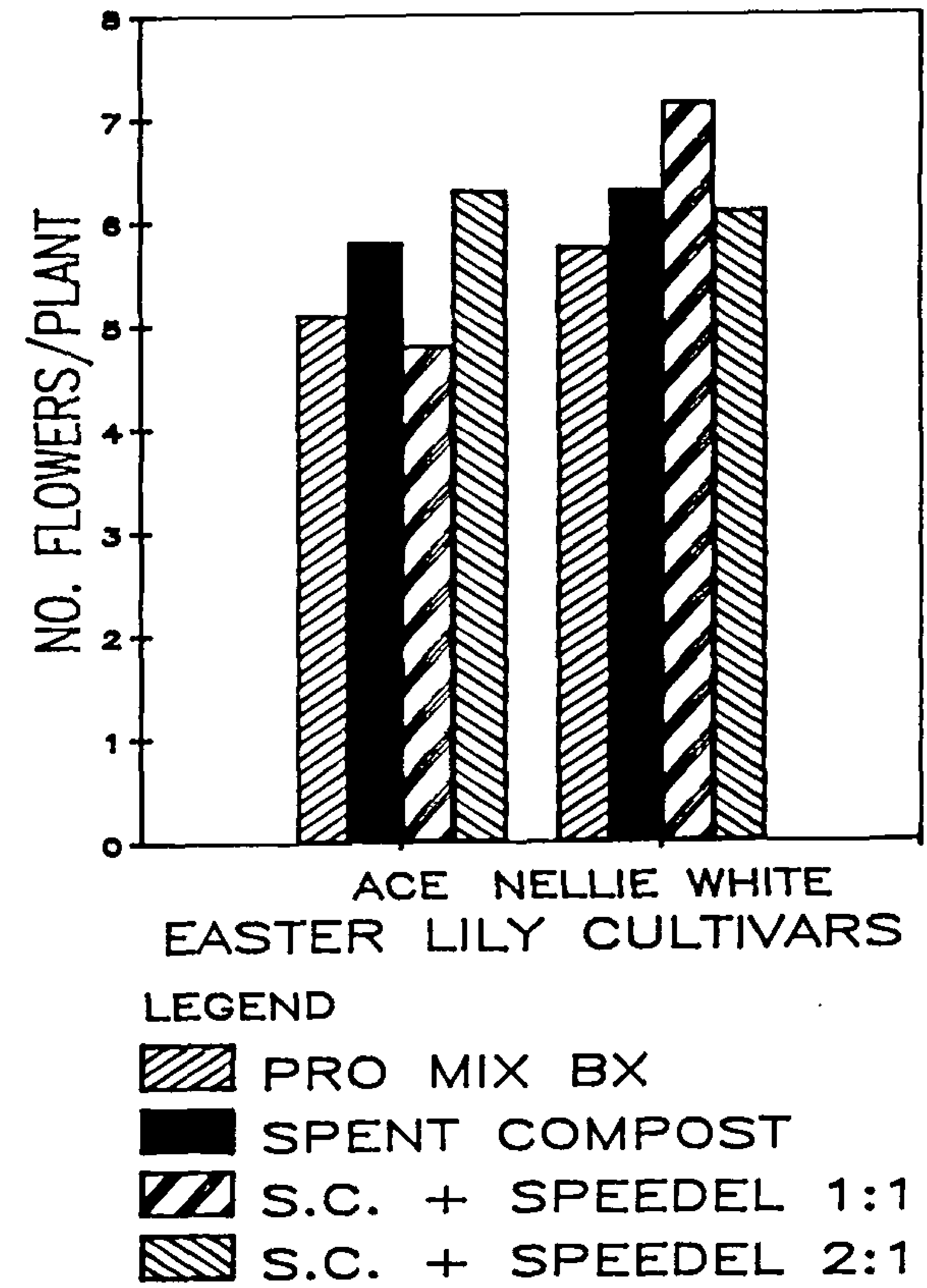

Figure 4. Effects of growing media on flowering in Easter lily, cvs. Ace and Nellie White.

HUGH STEVENSON: A comment on the use of mushroom compost. As the speaker mentioned, it must be weathered. We used fresh with disastrous results some years back.

BRUCE BRIGGS: Our mushroom compost has a high pH (7.0) because of high calcium and lime content. Since it is made with straw, it is also not stable over time.

PETER ORUM: We have used fresh mushroom compost as an additive for 20 years in our container mix. We use it fresh at a maximum of 25% with peat and sand for established plants, i.e. when going from 2 gal. into 5 gal. containers. For newly-rooted cuttings, 12 to 15% is maximum. It has a lot of soluble salts and must be used with caution.

DARELL APPS: The pH is lower now because the composting has changed with the use of sphagnum moss in the compost. I use it fresh with daylilies. Mix it half with bark or soil.

REST, POSTDORMANCY, AND WOODY PLANT SEED GERMINATION[1]

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Abstract. A phenomenon of significance to propagation by seeds having dormancies is the postdormancy as hypothesized by Vegis (12). Seeds of two cotoneaster species were used to test this hypothesis and both showed the postdormant condition. These results are discussed in relation to other work and practical considerations of afterripening and germination response of woody plant seeds. Length of moist-chilling, conditions on planting, fall planting, and implications to model systems, are discussed in relation to the postdormant condition of many woody plant seeds.

INTRODUCTION

Seeds of temperate zone woody plants, which develop during the summer, have produced mechanisms to prevent germination at inappropriate times in the fall. These mechanisms consist of internal conditions, called true dormancy (12), rest (9), or endo-dormancy (6), which prevent germination even though external conditions may be favorable. These mechanisms are usually modified by a period of moist-chilling (stratification) which, in the natural environment, is received by seeds during the winter. This can also be done by placing the seeds in moist material under refrigeration (3). Models have been developed (10) for dormancy modification as to chill units needed to satisfy the chilling requirement. After sufficient chilling is given, seeds would be expected to germinate at optimum germination temperatures.

A phenomenon of considerable practical significance but little understood by those developing terminology (6), or data for models (10), is the concept of postdormancy developed by Vegis (12). This concept can be simply stated as: after a period of moist-chilling that overcomes rest, seeds will germinate and grow at a narrow temperature range, but higher or lower temperatures will prevent germination. As more chilling time is given, the temperature range for germination and growth increases until after a long period of chilling the range is near the maximum and minimum for all growth processes. Although Vegis presented three scenarios for this phenomenon, the one perhaps most appropriate for temperate zone woody plants is that germination starts at an intermediate temperature range which continues to widen towards a maximum and minimum as longer periods of moist-chilling are given. This concept is graphically presented in Fig. 1. The reason that this phenomenon

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is not better understood is the magnitude of Vegis's article (12) published over 20 years ago, the way he presented his graphs, and the lack of subsequent experiments to directly test his hypothesis.

Experiments were designed to test this hypothesis using seeds of two species, *Cotoneaster apiculatus* and *C. divaricatus*. The reasons for selecting these species are given by Meyer (7).

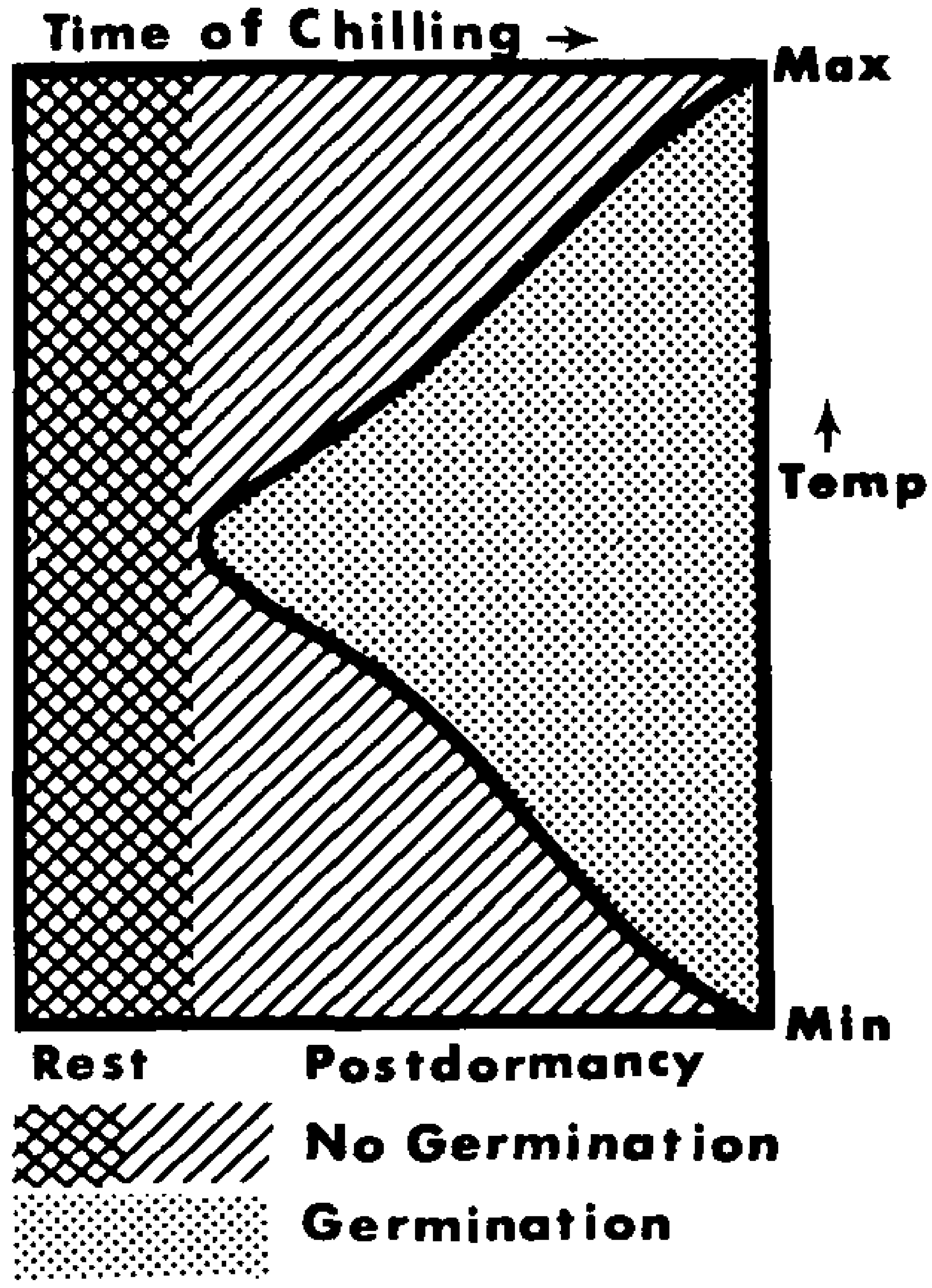

Figure 1. The postdormant condition hypothesized by Vegis which is relevant to woody plant seeds and buds where germination or budbreak starts at an intermediate temperature and widens as more chilling is given. Redrawn, with permission, from Annual Review of Plant Physiology, Vol. 15 © 1964 by Annual Reviews Inc.

MATERIALS AND METHODS

Seeds of these two species were collected on the University of Illinois campus in late September, extracted from the fruit, dried at 26°C, and stored dry at 2°C until used, but not over 130 days. At approximately 4 week intervals, lots of seed were treated for 90 min in concentrated H_2SO_4 (acid:seed, 2:1 v/v) maintained at 28 to 30°C and washed in running water for 4 hours. Seeds were then placed in moist vermiculite in lots of 50 seeds and maintained at 2°C until the germination treatments. Seeds were sown on steam pasteurized soil in 9×9×6 cm pots and covered 1.5 cm with moist vermiculite. The pots were placed in controlled temperature greenhouse compartments at 10, 15.6, 21, 26.7°C and in a cold storage at 4.4°C with light at 50 μmol s^{-1} m^{-2} for 16 hr days provided by cool white fluorescent lamps. There were 5 replicates of 50 seeds each for the storage germination treatments. The number of seedlings emerged were counted after 4 weeks.

RESULTS AND DISCUSSION

Both the chilling time and germination temperatures caused highly significant differences in germination percentage (Table 1). There was a highly significant interaction of these two factors, which can be predicted by the hypothesis of Vegis (12) for the post-dormant state. The data in Table 1 would appear to fit the hypothetical graph of postdormancy presented in Fig. 1 as seeds of both species showed greater temperature ranges for germination as the length of chilling increased.

Table 1. The influence of length of moist-chilling and germination temperature on seed germination during post dormancy of two cotoneaster species.

Cold treatment (Days at 2°C)	Germination temperature				
	40 / 4.4	50 / 10	60 / 15.6	70 / 21	80°F / 26.7°C
	Percent germination[z]				
			C. divaricatus		
0	0	0	0	0	0
30	0	0	0	0	0
58	0	0.8	0.8	0	0
87	10.4	57.2	43.6	30.4	10.4
116	70.8	82.8	80.4	72.0	77.6
			C. apiculatus		
0	0	0	0	0	0
30	0	0	0	0	0
58	0	12.0	7.6	0.8	0
87	0	36.4	36.8	15.2	2.4
116	20.4	29.2	31.2	28.0	11.2

[z] Analysis of variance showed a very high significance ($p < .001$) for days storage (D), germination temperature (T) and D × T interaction.

Some further corroborative evidence (which led to the above work) for the existence of the postdormant state of woody plant seeds can be seen in Fig. 2. This is a graphic presentation of work of DeHaas and Schander (1) on temperature and germination of apple seeds presented in the 2nd and 3rd editions of Hartmann and Kester's textbook (3). This work shows the widening range of temperature for germination when the seeds are germinated at temperatures which are also appropriate for moist-chilling (10). The lower the germination temperature the longer the chilling requirement before the seeds will germinate at that temperature. The post-dormant state is also apparent in the work of Greisbach and Voth (2) with daylily seed, but the intermediate temperature at which germination begins is higher than in the above two cotoneaster species.

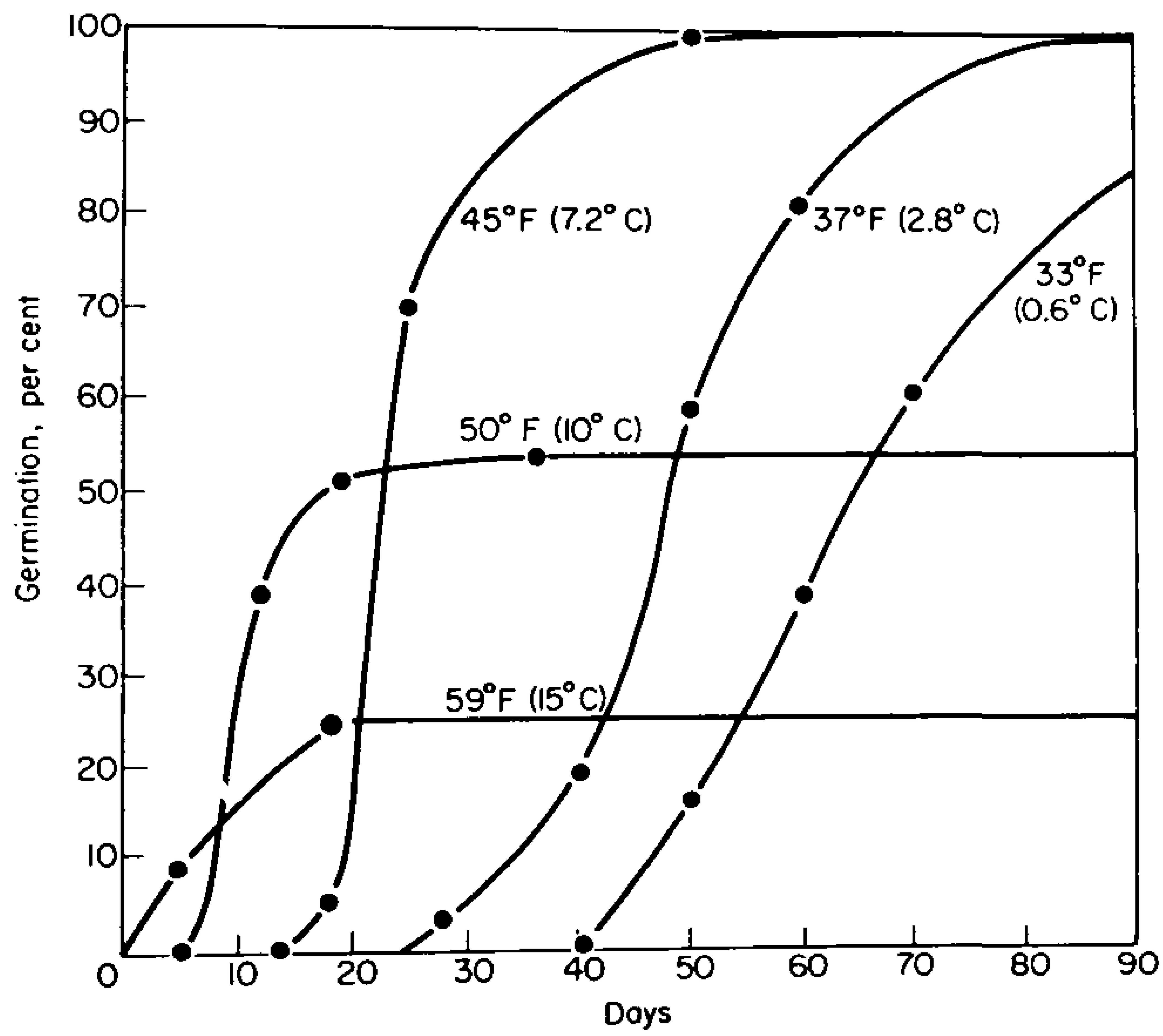

Figure 2. The effect of temperature on germination of apple seeds previously moist-chilled for 65 days at 3°C. Data from (1). When germination temperatures also induce afterripening, germination occurs when sufficient chilling overcomes the postdormant condition as can be seen in the lower part of Fig. 1. Reprinted from Hartmann and Kester (3) with permission from Prentice-Hall, Inc. © 1975.

The concept of postdormancy has considerable practical significance to the plant propagator. The postdormant state explains some of the controversy found in the literature regarding germination requirements. Recommended moist-chilling times for a single species of cotoneaster vary by as much as 60 days (11). This can be readily explained by considering the postdormant state. The researchers may germinate the chilled seeds at different temperatures, which will indicate that different lengths of chilling are needed (Fig. 1). A propagator who stratifies seeds of a woody plant species for comparable times in two different years, may find that the seedling crop is considerably better in one year than the other. This person might assume that one seed lot was poor. An alternate explanation could be that one year's seeds were planted during a warm spell with higher soil temperatures and some seeds were still in the postdormant condition.

The postdormant phenomenon may be related to the incomplete chilling that leads to dwarfism in seedlings, but may be present only towards the maximum temperature part of the response. Pollock (8) demonstrated that lower germination temperatures after incomplete chilling prevented dwarfism in peach seedlings. This obvious part of the postdormant phenomenon may be shown to be significant in the recommendations of Heit (4,5) that seeds of certain hardwood and conifer species germinated and grow better the first year when fall-planted rather than moist-chilled and planted in the spring. This may mean that the extended natural chilling and the gradual warming of the soil in the spring as the seeds are germinating prevent dwarfism associated with the postdormant state. In this case, the seeds go from chilling temperatures gradually through the intermediate temperatures where there is the least requirement of the postdormant state.

Another problem in storing stratified seeds is that the minimum germination temperature decreases over time in the postdormant state and eventually the germination temperature equals the stratification temperature resulting in immediate germination as seen in Fig. 2. Both species of cotoneaster showed this phenomenon at the 4.4°C germination temperature. Seed lots which had received shorter chilling times and had not germinated 4 weeks after planting at 4.4°C continued to be observed for another 3 months. These seed germinated at approximately monthly intervals respective to the time of chilling initiation. The postdormant phenomenon is why seeds cannot be stored moist for long periods of time or until the following season. Seeds stored under these conditions will eventually germinate right in the bag at refrigerator temperatures.

The embryo's sensitive response to slightly different temperatures in the postdormant state is difficult for the biochemist or molecular biologist to explain, but still is demonstrably present. The development of terminology for physiological research on dormancy by Lang et al. (6) that does not take into full account postdormancy is missing a significant practical concept. The development of data for chill units for fruit tree seeds (10) that uses only one germination temperature will lack a significant factor in using the model to explain the germination of seeds outside the laboratory. The understanding of postdormancy as advanced by Vegis (12) and presented in this paper has considerable significance in understanding the moist-chilling and germination response of many temperate zone woody plant seeds.

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RALPH SHUGERT: Just a comment. If you have fresh seed of *Picea Pungens* 'Glauca', fall sown in the U.S. Midwest with a mulch and seed germination occurs under the mulch, your crop will be dead the following spring.

DICK JAYNES: What effect does temperature have during the cold stratification period?

MARTIN MEYER: With apple seeds, there is not much difference between 2 and 6°C. However, since it is a biological process, 0°C or below should shut it down. Therefore, it would be satisfied better between 2 and 6°C than closer to 0°C.

MARK WIDRLECHNER: I can agree with your model for all the plants you mentioned which are all in the rose family.

DAVE BAKKER: What can I do to cause *Syringa reticulata* seeds to germinate in June instead of around Labor Day?

BILL BARNES: *Syringa* embryos, and many other Oleaceae species, have an immature embryo and are what we call summer dormancy. The seeds require a period of afterripening at warm temperature, after which a cold period will satisfy the dormancy requirement.

DAVID VANSTONE: We found that 2 months at 5°C followed by 2½ months at 20°C will produce prompt spring germination.

INTRODUCING NEW AND RECOMMENDED PLANTS INTO THE NURSERY INDUSTRY OF BRITISH COLUMBIA

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The Plant Introduction Scheme at the University of British Columbia Botanical Garden (P.I.S.B.G.) was initiated in 1980 by the Garden's past Director, Dr. Roy L. Taylor. The aims and procedures of the program to introduce plants into the nursery and the role of the eleven test sites across North America, have been previously documented in the IPPS Proceedings (1, 2). The purpose of this paper is to summarize the progress to date, review some of the ongoing work, relate our plans to develop an endowment foundation for the program, and conclude with a tabulated appendix (see end of paper) on the best to-date methods for propagation of these plants.

The cooperation between the UBG Botanical Garden (hereafter referred to as Garden) and the nursery and landscape industries has been the major factor in the program's success. Currently, there are some 26 participator nurseries in British Columbia and well over 1,500,000 plants have been produced from the first six public releases—*Arctostaphylos uva-ursi* 'Vancouver Jade', *Genista pilosa* 'Vancouver Gold', *Microbiota decussata* (UBC Clone # 12701), *Viburnum plicatum* 'Summer Snowflake', *Rubus calycinoides* 'Emerald Carpet' and *Anagallis monelli* 'Pacific Blue'. In addition to sales in Canada, these plants have been exported to the United States, Britain, Denmark, Holland, France, Korea, and Japan. Another important factor to assist sales has been publicity, for example, the fact sheets produced by the Garden. Each fact sheet has a color picture of the plant on the front, with information on the reverse side regarding landscape use, hardiness, propagation, and other relevant points on culture.

Clonal selection and breeding. Clonal selection of native plants is an important aspect of the P.I.S.B.G. program. It is well known that many native species show considerable genetic variation in the wild. Traditionally, nurserymen have collected their material in the wild for vegetative propagation. Propagation from wild stock subsequently leads to considerable variation in rooting potential, habit, leaf and flower color and, in some cases, tolerance to disease. These factors often lead to a considerable variation in crop quality. Clonal selection can be illustrated by the following examples.

[1] Director

1) *Arctostaphylos uva-ursi* (kinnikinnick or bearberry). This ground cover is used heavily by the landscape industries in the Pacific Northwest. Much variation exists in native plants and there was a real need for an improved local selection. The plant finally chosen was one that the late Mr. E. H. Lohbrunner selected from his own plants some years ago. The Garden registered it with the Canadian Ornamental Plant Foundation (COPF) and introduced it as *A. uva-ursi* 'Vancouver Jade'. It is vigorous, spreads uniformly, has bright green foliage that takes on plum-purple colorations in the winter, carries fragrant clusters of pink flowers well above the foliage in early spring, is more resistant to pathogens affecting the leaves and young shoots, roots with over a 90% success rate, and produces a quality container product.

2) *Vaccinium ovatum* (evergreen huckleberry). This plant shows considerable variability in growth habit, leaf shape, and stem and leaf color—particularly in the degree of red pigmentation in the new growth in spring. The selected plant has abundant flowering and particularly good reddish-bronze new growth. It is currently being multiplied to provide mother plants to send to the participator nurseries in 1989.

3) *Paxistima myrsinites* (Oregon boxwood). There has been a particular interest in this plant from the landscape and highway department for planting in the dryer interior areas of our Province. Again, there is considerable variation in habit and leaf size when using plants propagated from wild collections. The plant finally selected and named *P. myrsinites* 'Emerald Cascade' was from wild collections made by the Garden's Native Garden Curator, Al Rose. The new growth is bright green, and has a very appealing weeping habit. Initial trials at our nursery showed that the plants were susceptible to *Pythium* and *Phytophthora* root rot with overhead irrigation systems used on the coast. This resulted in our withholding the plant from introduction to the participator nurseries. However, further trials and observations at two commercial nurseries lead us to believe that this plant will be introduced within the next 2 to 3 years.

About 31 members of the evaluation panel met in July to review the collections established at the Garden's nursery for potential introduction. This resulted in five plants being selected for possible distribution to participator nurseries.

The Garden's Research Scientist, Dr. Gerald B. Straley, has continued his breeding research work with *Alstroemeria, Meconopsis, Phygelius,* and *Schizostylis.* In *Alstroemeria* he is using mainly the species *A. haemantha* for compactness, *A. aurantiaca* for hardiness, and the Ligtu hybrids for their range of color, to create hybrids that will enable this genus to be more widely used in gardens. He is using the Garden's *Meconopsis* collections to isolate plants of the very attractive blue *Meconopsis betonicifolia* which are demonstrating potential true perennial characteristics. An interesting color range is developing from crossing the red-flowered *Phygelius capensis* with the pale yellow *P. aqualis* 'Yellow Trumpet'. The first generation hybrids have been crossed back with the two parents. The attractive red-flowered *Schizostylis coccinea* has performed particularly well as a late-season garden plant in Vancouver. A limited range of hybrids with flowers of pale pink to bright red hues are available in the trade from some specialist nurseries. Dr. Straley's goals are to create hybrids which have shorter stems, flower earlier so that petals do not deteriorate so rapidly in the seasonal heavy rains in this area, and to produce a white-flowered cultivar.

Future releases. Our experiences have shown that only two or three plants should be introduced in any one year if each plant is to become well-known and accepted by the nursery and landscape industries. However, it is appreciated that this goal may vary according to the aims and development of plant introduction programs from other institutions.

One new plant to be released in March, 1988, is an attractive, white-flowering form of the native *Ribes sanguineum* with the cultivar name 'White Icicle'. It is thought to have originated in Victoria, B.C. 'White Icicle' grows to about 10 ft (3.0 m) in height and 7 ft (2.0 m) in width, with flower racemes that are 4–5 in. (10–13 cm) in length. It is very effective in mass landscape plantings, particularly when mixed with the red forms for contrast. It should be hardy to USDA Zone 6/Canada Zone 6b–7a. This cultivar is registered with the Canadian Ornamental Plant Foundation.

Two other plants to be publicly released in March, 1988, are not new plants but two perennials which, in our experience, should be made much more available in British Columbia and perhaps other areas of North America. They can sometimes be found listed in specialist plant nurseries in North America and Europe. The first is *Diascia rigescens* (twinspur or bride's saddle), a native of South Africa that flowers intensively through the summer months. Its growth habit and bright pink flowers make it desirable for bedding, patio and container uses. The spent flowering shoots should be removed to encourage further flowering. It is hardy to USDA Zone 7/Canada Zone 7b–8a, and should be treated in cold areas as an annual and propagated each year from plants overwintered in a greenhouse.

The second perennial is the little-known *Teucrium scorodonia* 'Crispum' (crispy wood sage). The species is native to Europe and has become naturalized in Eastern North America. The plant grows to 18 in. (45 cm) in height and is unique because of the attractive ruffled margin to the lime-green leaves. The foliage texture has good retail potential for use in mixed plantings of annuals and perennials, hanging baskets and other containers. Frequent shearing promotes vigorous new growth, especially when being grown for its foliage. It should be hardy to USDA Zone 5 or 6/Canada Zone 5b–7a.

There are currently nine plants that are being developed and researched to ascertain the correct production schedules before being distributed to the participator nurseries. It is important that the continuity of the program be ensured by always having plants in the system at various stages of evaluation and testing, ready for subsequent introduction. Conversely, it is just as important to discard plants that have not attained the program's objectives before they are released into commercial production.

Future funding—establishment of the Henry M. Eddie Plant Development Foundation. Matching funding for the program was obtained initially through grants from the Science Council of British Columbia and the Devonian Group of Charitable Foundations in Calgary. Additional income has been received by the payment of royalties through the Canadian Ornamental Plant Foundation and from the sale of mother plants and unrooted cuttings. This income from the first six releases now amounts to over $70,000.

What has been particularly rewarding is that an independent economist, hired by the Science Council of British Columbia to evaluate the direct economic benefit to industry from their different programs, reported the following about the P.I.S.B.G. program: ". . . sales in 1985 were just under $600,000. The administrators of the program were surprised to find that a significant portion of those sales were to buyers in the Eastern United States and Western Europe. Estimates for 1986 are for sales of $1.2 million, and in 1987, $1.9 million".

The two initial grants have completed their terms and the P.I.S.B.G. program now has to be self-financing. Currently, the funds generated from the royalty income are not sufficient to fully support the program. Following discussions with the Garden, the nursery industry proposed the formation of an endowment program to ensure long-term support.

The foundation has been named the Henry M. Eddie Plant Development Foundation. Henry M. Eddie, born in Scotland, was one of British Columbia's most important pioneer nurserymen. Besides his expertise as a nurseryman, he achieved international acclaim for his breeding of roses, fruit trees, and dogwoods. His most renowned hybrid was the result of a cross made in the 1940's between *Cornus nuttallii* and *C. florida*, subsequently named *C.* 'Eddie's White Wonder'.

A ten-member Board will be appointed, half of whom will represent the nursery industry. The terms of reference for this Board will be essentially three-fold:

1) Advise the Garden on potential sources of funding from government, industry, and private sources; assist the

Garden in achieving donations from such sources; and ensure the Garden is maximizing sources of revenue from plant sales, e.g., royalties and trademarks.

2) Oversee the administration of funds received and their utilization at the Botanical Garden for the purposes intended.

3) Undertake to canvass potential donors and keep the nursery industry and others aware of the work of the P.I.S.B.G., the Gardens, and other University facilities.

The revenue received from royalties and the foundation will be used largely to:

1) Introduce new and recommended plants from the Garden's collections into the commercial nursery trade.

2) Provide increased revenue to the British Columbia nursery industry for provincial, national, and particularly, export sales.

3) Establish breeding programs of hardy woody and perennial plants using the Garden's collections.

4) Proceed with the clonal selection of native and existing commercial plants to improve the current genetical material.

5) Encourage international field collections to ensure wild collected material continues to improve the Garden's collections.

6) To develop new technology for the establishment of new plant material.

CONCLUSIONS

We have all learned a great deal from both our successes and mistakes. The program has been of direct financial benefit to the industry and the Garden. We have been very encouraged by the help and interest given to us from across Canada, North America, and some European countries. It has also been rewarding to see that some other gardens and institutions have adapted the P.I.S.B.G. program to suit their own requirements—for example, the Royal Botanical Gardens, Hamilton, Ontario, the Chicago Botanic Garden, Glencoe, Illinois, and the North of Scotland College of Agriculture, Aberdeen. There is also considerable interest in starting similar programs in Australia, New Zealand, and South Africa. Through effective communication and cooperation with the nursery and landscape industries, plant introduction programs allow botanical gardens to show considerable leadership and help to ensure that plants from their collections are made available to beautify home and public landscapes.

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APPENDIX

A tabulated guide to the methods used to propagate P.I.S.B.G. introductions from the University of British Columbia Botanical Garden

Species/cultivar	Method of propagation	Comments
Anagallis monelli 'Pacific Blue'	Softwood cuttings from March through to April. Can commence February from stock plants over-wintered in a greenhouse. Rooting hormone not necessary. Growing tips of cuttings should be removed.	Tend to deteriorate if not removed from propagation facility following rooting. Rooting medium must be well-drained. Consider using 2:1 ratio of perlite and peat.
Arctostaphylos uva-ursi 'Vancouver Jade'	Semi-ripewood/evergreen hardwood heel or nodal cuttings from July to January, using a rooting hormone of 0.8% IBA in talc. Benefits gained by wounding cuttings taken November to January	Some propagators in B.C. have had inconsistent results in July and August. Rooting success rates over 90% achieved October–January. Must avoid excessive misting in fall and winter, otherwise cuttings prone to fungal infections.
Diascia rigescens	Softwood cuttings April to early September. Rooting hormone not normally required; use 0.1% IBA in talc, if necessary	Rooted cuttings and liners are prone to *Botrytis cinerea* (gray mold) infection, particularly in late winter and early spring. Regular sprays at 2–3 week intervals are recommended, alternating glycophene (Rovral ®) with benomyl (Benlate ®) in areas where this problem occurs.

Note:
(i) Standard rooting medium: perlite:peat moss (2:1, v/v) with basal temperature 65 to 70°F (18–21°C)
(ii) Propagation facility—mist, fog, or plastic film with the latter particularly for late fall and winter sticking
(iii) All plants lend themselves to direct sticking in liner pots except, in some instances, *Anagallis monelli* 'Pacific Blue'

Species/cultivar	Method of propagation	Comments
Genista pilosa 'Vancouver Gold'	Multi-branched semi-hardwood cuttings 3–4" (7.5–10 cm) in length during July to November. Rooting hormone during summer is not necessary, but 0.5–0.8% is beneficial for fall rooting.	Lends itself to rooting in cold frames.
Microbiota decussata (UBC Clone # 12701)	Root as semi-ripewood/evergreen hardwood cuttings from August–January with at least 1" (2.5 cm) of the previous year's wood included at the base. Rooting hormone of 0.8% IBA in talc or 0.25% IBA solution is advised, particularly for winter sticking.	Experience in B.C. has shown that a variable percentage of plants die following over-watering in containers, but no pathogen found. Over-wintering outdoors in high rainfall areas seems to encourage this condition. Stock plants showing gray/green fading of foliage must be discarded.
Teucrium scorodonia 'Crispum'	Easily rooted form softwood and semi-ripewood cuttings from March to October. Rooting hormone not necessary, but 0.1–0.3% IBA in talc can be helpful for late summer and fall rooting.	
Ribes sanguineum 'White Icicle'	Softwood or semi-ripewood nodal cuttings 4" (10 cm) in length. Alternatively, root as dormant leafless hardwood cuttings in late fall-early winter, applying 0.8% IBA in talc or 0.1% IBA in solution.	Over-wintering problems can occur if semi-ripewood cuttings are rooted later than late summer.
Rubus claycinoides 'Emerald Carpet'	Can be rooted virtually year-round from softwood and semi-ripewood cuttings. No rooting hormone necessary.	In cold and exposed areas, the stock plants should be protected during winter months.
Viburnum plicatum 'Summer Snowflake'	Nodal softwood cuttings 3–4" (7.5–10 cm) from June–August, using a rooting hormone of 0.3–0.5% IBA in talc. Due to the length of internodes, it is often easier to prepare a single nodal cutting with a pair of opposite buds (the	Care is required when over-wintering—cuttings should not be stuck later than mid-August and the rooting medium must be kept relatively dry. All leaves should be removed at leaf fall to

Species/cultivar	Method of propagation	Comments
	stem is cut internodally at the appropriate length).	reduce the risk of fungal infection. Consider removing flower buds of liners in early spring to encourage vegetative growth. Rooting period can be extended by taking cuttings in April from stock plants sited in a greenhouse—flower buds should be removed.

DOVE TREE (*DAVIDIA INVOLUCRATA* VAR. *VILMORINIANA*) AND ITS PROPAGATION BY SEEDS

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Davidia, one of the most unusual trees growing in the Arnold Arboretum, Jamaica Plain, Massachusetts, was introduced to horticulture from China. Abbe Armand David, a French missionary, discovered it while botanizing in the mountains west of Szechuan, China, and sent specimens to Paris, France, where it was described and named after him. Credit for its introduction to horticulture, however, goes to Pere Farges, another missionary who in 1897 sent 37 nuts to the Vilmorin Arboretum at Les Barres in France. From this shipment one seedling germinated in 1899. Two cuttings and one layer were propagated from it. The cuttings were provided to botanical institutions in Europe; the rooted layer was sent to the Arnold Arboretum in 1904 and there it still grows. This particular strain was determined to be different enough from the species to warrant a varietal name and therefore became *Davidia involucrata* var. *vilmoriniana.*

In Rehder's Manual of Cultivated Trees and Shrubs, *Davidia involucrata* is listed as being hardy in Zone 6 (−5° to +5°F) while the variety *vilmoriniana* is rated as being hardy in Zone 5 (−10° to −5°F). During the winter of 1933–34 *D. involucrata* var. *vilmoriniana* was killed to the ground at the Arnold Arboretum, but sprouted from the roots and is now a tree with six trunks. It should be noted that the winter of 1933–34 had some of the lowest temperatures ever recorded in the northeastern United States. On rare occasions the

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Davidia, one of the most unusual trees growing in the Arnold Arboretum, Jamaica Plain, Massachusetts, was introduced to horticulture from China. Abbe Armand David, a French missionary, discovered it while botanizing in the mountains west of Szechuan, China, and sent specimens to Paris, France, where it was described and named after him. Credit for its introduction to horticulture, however, goes to Pere Farges, another missionary who in 1897 sent 37 nuts to the Vilmorin Arboretum at Les Barres in France. From this shipment one seedling germinated in 1899. Two cuttings and one layer were propagated from it. The cuttings were provided to botanical institutions in Europe; the rooted layer was sent to the Arnold Arboretum in 1904 and there it still grows. This particular strain was determined to be different enough from the species to warrant a varietal name and therefore became *Davidia involucrata* var. *vilmoriniana.*

In Rehder's Manual of Cultivated Trees and Shrubs, *Davidia involucrata* is listed as being hardy in Zone 6 (−5° to +5°F) while the variety *vilmoriniana* is rated as being hardy in Zone 5 (−10° to −5°F). During the winter of 1933–34 *D. involucrata* var. *vilmoriniana* was killed to the ground at the Arnold Arboretum, but sprouted from the roots and is now a tree with six trunks. It should be noted that the winter of 1933–34 had some of the lowest temperatures ever recorded in the northeastern United States. On rare occasions the partly dehardened flower buds have been destroyed by late frosts.

Flowers and Fruits. Both the flowers and fruits of *Davidia* present some highly unusual characteristics. In the area of Boston, Massachusetts, flowers appear during May. They are bunched in a rounded head about ¾ in. in diameter. The impressive feature is the two very large white bracts that subtend the flowers. These are unequal in size with the lower being much the larger. When one looks at the serrated margins and their vein patterns it becomes obvious that the bracts are modified leaves.

The fruits are about 1½ in. long and elliptical in shape. Each contains an extremely hard stone in which seeds (sometimes only one, but more frequently two to five, and rarely more) are arranged around a central axis. The stones are so hard that I have had to clamp them in a vise and cut their walls with a hacksaw to count the numbers of seeds.

Germination of the Seeds. For many years the germination behavior of *Davidia* seeds was unknown and propagators planted them out-of-doors as soon as possible with the thought that seasonal changes would prepare them for germination. This was a common practice years ago when little was known about protective barriers that had evolved to prevent seeds from germinating at times unfavorable to seedling survival. Ernest Wilson, writing in 1929, said of *Davidia*, "The nuts with pulp removed should be sown out-of-doors so soon after they are ripe as is possible, say in November. If there be much delay in sowing the seeds, the probability is that they will not germinate until spring of the second season." Older Arnold Arboretum records show erratic patterns of *Davidia* seed behavior with sparse germination strung out for a couple of years in some cases.

The handling and pretreatment of *Davidia* seeds can be simplified and hastened by the use of plastic bags. After the leaves have fallen, the fruits remain on the trees and can be easily seen for collection. When placed in a plastic bag in a warm location for a week or two, the fleshy pulp softens and can be separated from the nuts by kneading while still in the bag.

Germination of *Davidia* seeds is very peculiar. Two hundred nuts planted about 1 in. deep in plastic flats were placed in a warm greenhouse. After a period of six months, sections of the nut walls were pushed out by partial development of the seedlings. When this became a general condition the trays were transferred to a 40°F refrigerator for 3 months. Three trays were left in the warm situation as a control.

When those moved to cold were returned to warm conditions, a general germination took place. In the three control trays (not provided with cold) there was no seedling development.

In the natural scheme of seed dispersal, adaptations have evolved which usually lead to the seeds being scattered. Seeds of

Davidia, however, are packed closely together within a nut. They germinate simultaneously and this leads to a tight cluster of seedlings competing with one another.

An efficient method of pretreating *Davidia* seeds is by the use of polyethylene plastic bags. A medium of sand and peat moss in equal parts is combined with the nuts and placed in the bags. In proportion, the medium would be three or four times the volume of the seeds. It should be moist but not wet. Binding the top of the bag with a rubber band makes the unit vapor proof for the entire stratification period. With this method any change that takes place within can be observed through the transparent wall of the bag. By using the timing described above, germination should follow.

BOTTLE BRUSH BUCKEYE (*AESCULUS PARVIFLORA*) AND ITS PROPAGATION

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Aesculus parviflora, the bottle brush buckeye, is native to South Carolina, Georgia, Florida, and Alabama, and differs from other members of the horsechestnut family in several ways. It is not a tree but a large shrub that spreads by stoloniferous shoots forming a thicket about 10 ft tall. In the area of Boston, Massachusetts, it flowers in July long after other members of the genus have done so and at a time when there are but few woody plants in flower. It is quite shade tolerant and creates an impressive display when planted at the edge of a field or along a roadside against a background of trees. Other attributes are freedom from insect and disease problems, good yellow autumn color, and the ability to remain free of competing vegetation. Despite its southern origin, Rehder's Manual (1) rates *A. parviflora* as a Zone 4 plant, capable of surviving temperatures to −20°F.

Flowers and Fruiting. In July, highly conspicuous upright panicles of flowers develop above the plant on terminal shoots. It is astonishing to see the profusion of pollinating insects that visit to work the flowers. Various kinds of butterflies, bees, bumblebees, and wasps all appear in abundance. Both staminate and hermaphroditic flowers are present and fruit production is relatively sparse.

This year (1987), the fruits were ready for collection by late September. The fruits were loosely attached, the husks were

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This year (1987), the fruits were ready for collection by late September. The fruits were loosely attached, the husks were starting to split, and a few husks on the ground indicated that seeds had been carried away by squirrels.

The seeds are microbiotic and their period of viability is very short; as a result they were processed within two days. Some kept at room temperature without protection shrivelled and became worthless in 16 days. Others put in sealed plastic bags and placed in a 40°F refrigerator underwent partial germination and then decomposed. *Aesculus* seeds contain no endosperm but have very large fleshy cotyledons containing stored food for the initial growth of the seedlings. Seeds of most *Aesculus* species have dormant conditions that must be overcome by a period of cold. Natural dispersal is carried out by squirrels that take the fruits from the trees in autumn, remove the husks, and bury the seeds to a depth of 1½ or 2 in. Winter satisfies the cold requirement, and germination takes place during the warm days of spring.

Seeds of *A. parviflora,* however, ripen in late September and germinate a few days thereafter. In the process of germination the cotyledon petioles elongate and carry the rudimentary plant out through the seed coat. In a few weeks the ample food reserves present in the cotyledon are exhausted by the rapid development of the large, carrot-like root system. Meanwhile the epicotyl has extended to a length of about an inch or less and has become dormant. Squirrels bury the seeds to a depth where the seedlings remain below the surface of the soil and those germinating in autumn are protected thereby surviving the winter. Occasionally the epicotyl fails to remain dormant and continues to develop. Seedlings which do this have shoots above the ground and may be eliminated in the course of natural selection. To test this, I planted a number of seeds in my home garden and covered them with a ½ in. steel hardware cloth to prevent them from being dug up by squirrels. However, in this batch none were precocious and all epicotyls remained below ground. A carefree method of propagating bottle brush buckeye from seeds would be to use this procedure.

Treatment of Seeds. On October 3, seeds were planted 1½ in. deep in plastic trays. They were kept in a greenhouse until the seedlings were fully developed and had gone dormant. At this time the food stored in the cotyledons was completely exhausted, and the seed coats were hollow shells. On the 21st of November the dormant seedlings were placed in a cold storage unit where the temperature is maintained at about 36°F. On the 13th of February they were returned to a warm greenhouse where the epicotyls started pushing through the soil in a week's time.

Two hundred and eighteen seedlings developed. Of these, 16% were albino. This is a lethal mutation, as without chlorophyll the plant cannot function, and it dies. As a matter of curiosity I grafted some albino stems on normal plants. The albino part was parasitic on the normal plant. When planted in the nursery they stumbled along for several years with each part foliating in spring and defoliating in autumn. I wondered if the albinism might be caused by inbreeding. Where these masses of plants spread by sucker growths, the clump could very well be all one clone. I spoke to several plant physiologists about this and asked if this might be true. In their opinions, there was no doubt that it was.

Aesculus parviflora var. *serotina*. This variety differs from the species in a number of ways. It grows about twice as tall, flowers during the first half of August while the typical form blossoms in mid-July, and is also more prolific. Two or three seeds are often found in a capsule, while the species usually has one.

Aesculus parviflora can be propagated by root cuttings or root suckers can be collected from the bases of existing plants.

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1. Rehder, Alfred. 1940. *Manual of Cultivated Trees and Shrubs*. The Macmillan Company, New York, N.Y.

SPENT MUSHROOM COMPOST AND PAPERMILL SLUDGE AS SOIL AMENDMENTS FOR CONTAINERIZED NURSERY CROPS

CALVIN CHONG, R. A. CLINE, and D. L. RINKER

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Abstract. Two sources of mushroom compost were evaluated as soil amendments with bark: (1) unweathered (UMC) in proportions of 25, 50, 75 and 100% by volume, and (2) weathered (WMC) in proportions of 25, 50 and 75%. There was also a 100% bark control treatment. Both red osier dogwood (*Cornus stolonifera* [syn. *C. sericea*]) and forsythia (*Forsythia* × *intermedia* 'Lynwood') grew well in all media. While plant height was little affected by the amount of mushroom compost in the media, top dry weight of the two species was increased in proportion to the amount of both UMC and WMC. Regardless of the media treatment, there was no apparent symptoms of nutrient toxicity or deficiency.

Of four types of papermill sludge (primary, secondary, mixture of primary and secondary from Ontario Paper Co., and a mixture of primary and secondary from Fraser Paper Co.) added at 33% by volume to bark, secondary sludge which has the highest N content provided the best growth of spiraea (*Spiraea* × *bumalda*); however, foliage of plants was dark blue-green in color reflecting high N. Unacceptably poor growth occurred in Fraser-amended media because of low N.

INTRODUCTION

During the past 20 years, there has been considerable interest in the use of various organic and woody waste by-products in agriculture (4,6,10). The type and availability of these products varies along for several years with each part foliating in spring and defoliating in autumn. I wondered if the albinism might be caused by inbreeding. Where these masses of plants spread by sucker growths, the clump could very well be all one clone. I spoke to several plant physiologists about this and asked if this might be true. In their opinions, there was no doubt that it was.

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INTRODUCTION

During the past 20 years, there has been considerable interest in the use of various organic and woody waste by-products in agriculture (4,6,10). The type and availability of these products varies widely in different locations. In southern Ontario, the availability of large quantities of spent mushroom compost and papermill sludge at little or no cost make these by-products attractive for use as inexpensive growing media additives in nursery container culture.

Mushroom compost has been used as soil amendment for various crops including vegetables (11) and greenhouse crops (8). Papermill sludge is also being evaluated for use on various crops (5,7) and one company, after years of research, has marketed a growing medium (Grow Rich) derived primarily from this type of waste (1). Compost derived from papermill wood waste and poultry manure was used as an organic amendment of a container growing mix (6).

Such waste products seem to be promising alternatives for improving the physical properties of container mixes and also the nutrient resources. However, there are several potential disadvantages to plants encountered from the application of such waste products: accumulation of total salts in the media, specific toxicities due to particular nutrients, and variation in response due to species (6, 8, 11).

As part of a research program which focuses on the adaptation of nursery crops to container culture, this study was conducted to determine the influence of mushroom compost and papermill sludge as soil amendments for use in container crop culture.

MATERIALS AND METHODS

Mushroom Compost. In 1986, two sources of spent mushroom compost, previously used in the cultivation of the commercial mushroom, *Agaricus brunnescens,* were evaluated. The first was a weathered mushroom compost (WMC), which had been discarded on an open field and exposed to weathering for two years. The second was an unweathered mushroom compost (UMC) obtained from the cropping area of the Horticultural Research Institute of Ontario mushroom programme and used soon thereafter without exposure to weathering.

Media treatments potted in 6-l (2 gal. trade size) nursery containers consisted of: 25, 50, 75, and 100% by volume of WMC mixed with 75, 50, 25, and 0% of bark; 25, 50, and 75% UMC also mixed with bark; 100% bark (control). Selected physical characteristics of these media are shown in Table 1. A treatment with 100% UMC was not included since it was believed that excessive salts (1,226 mhos $\times 10^{-5}$) in this treatment at planting time would be detrimental.

In mid-May, rooted hardwood cuttings of dogwood (*Cornus stolonifera*) or forsythia (*Forsythia* × *intermedia* 'Lynwood') were planted in each medium treatment. For each species, containers were spaced 45 cm × 45 cm arranged in a randomized complete

Table 1. Characteristics of media amended with weathered (WMC) and unweathered (UMC) mushroom compost.

Source	% Compost	Soluble salts (mhos × 10^{-5}) Planting	Harvest	pH Planting	Harvest	Shrinkage (cm)
Bark (control)	0	3	62	4.2	6.4	1.31
WMC	25	17	66	6.0	6.8	1.81
	50	39	67	6.5	6.9	2.23
	75	62	70	6.8	7.1	2.43
	100	83	72	7.0	7.1	2.20
UMC	25	35	82	6.2	6.7	1.92
	50	63	94	6.6	6.9	2.72
	75	1030	101	7.9	7.0	3.24

block design outside in a container nursery with four replications of each treatment. There were five plants in each treatment unit. Plants were fertilized 2 to 3 times per week with 20-20-20 and watered as needed. In mid-August samples of leaves were taken for analysis of N, P, K, Ca, Mg, Fe, Mn, Zn, and B. In mid-September, media shrinkage determined by depth from the container rim (Table 1), plant height, and top dry weight were determined. The pH and total soluble salts were determined from a 1:2 soil:water (by volume) extract of all media at planting time and also at harvest (Table 1).

Papermill Sludge. In 1985, four types of papermill sludge, each added at 33% by volume to bark, were evaluated: a primary sludge; a secondary sludge; and a mixture of 20% of primary and 80% secondary sludges from the Ontario Paper Co.; a mixture of primary and secondary sludges from the Fraser Paper Co. Using spiraea (*Spiraea* × *bumalda*) as test species, selected media characteristics (Table 2), experimental design, and growth measurements were as described above. Leaf samples taken from mature leaves in the centre of the current season's growth in early October were analyzed for N, P, and K.

Table 2. Characteristics of media amended with different types of papermill sludge.

Type	% Sludge	Soluble salts (mhos × 10^{-5}) Planting	Harvest	pH Planting	Harvest	Shrinkage (cm)
Bark Control	0	10	41	5.8	5.3	2.5
Primary	33	29	38	6.2	5.8	4.7
Secondary	33	108	43	7.4	5.0	5.6
Ontario Mixture	33	29	13	6.9	5.3	4.3
Fraser Mixture	33	30	50	7.4	6.0	6.3

RESULTS AND DISCUSSION

Mushroom Compost. Both dogwood and forsythia grew vigorously during the season in all media treatments. While plant height was little affected by the amount of mushroom compost in the medium (data not shown), top dry weight of the two species increased significantly with increases in the proportion of both sources of mushroom compost (Fig. 1).

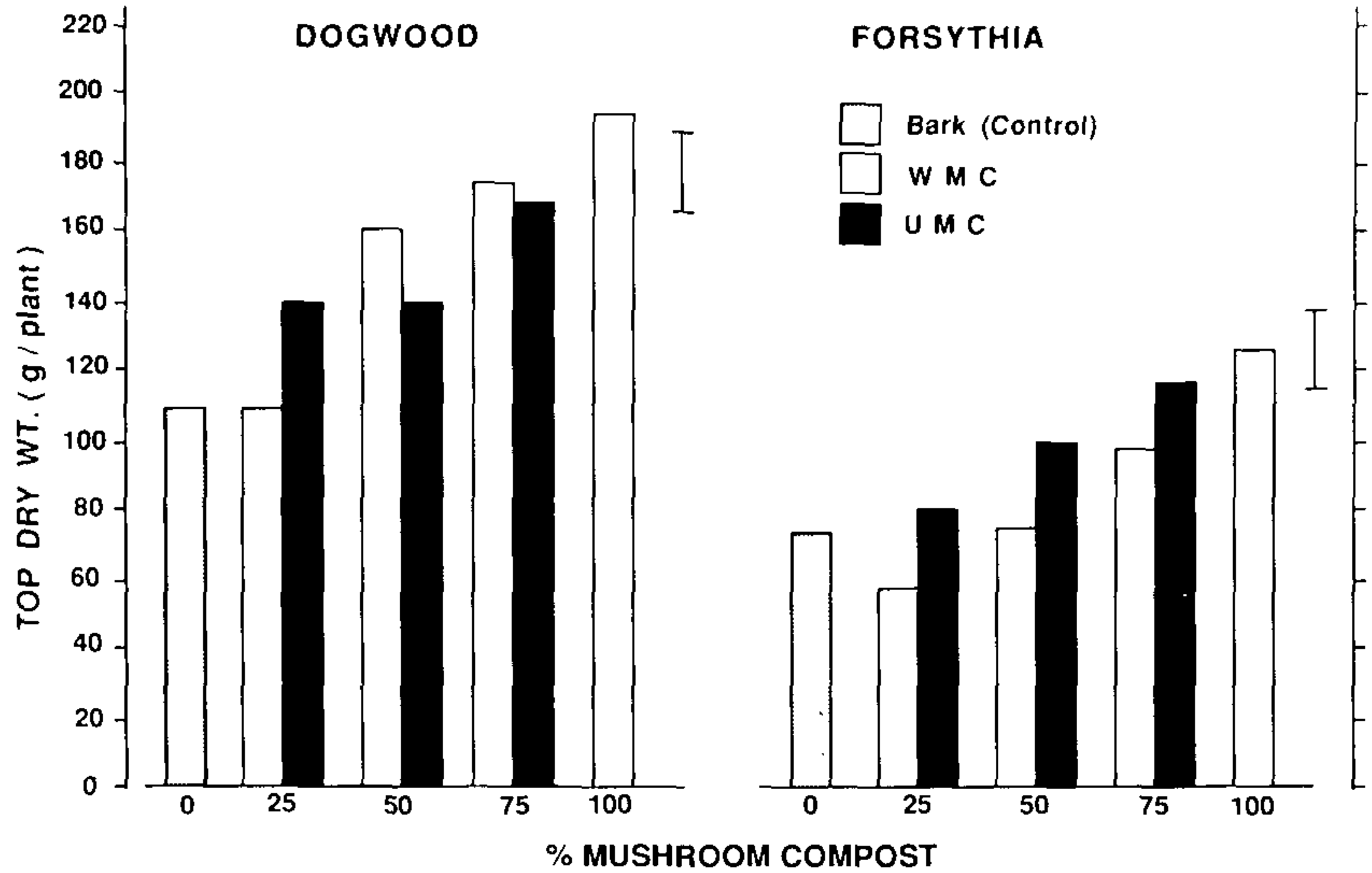

Figure 1. Top dry weight of dogwood and forsythia grown in media amended with weathered (WMC) and unweathered (UMC) mushroom compost. Vertical bars represent LSD at 1% level.

Table 3. Nutrient analysis in leaves of dogwood grown in media amended with weathered (WMC) and unweathered (UMC) mushroom compost.

		Percent dry wt					ppm			
Source	Compost	N	P	K	Ca	Mg	Fe	Mn	Zn	B
Bark (Control)	0%	2.17	0.58	1.27	2.12	0.33	55	22	27	27
WMC	25%	2.42	0.76	1.27	2.74	0.35	72	33	28	25
	50	2.36	0.77	1.23	2.60	0.34	58	24	26	24
	75	2.45	0.81	1.31	2.50	0.33	57	33	35	28
	100	2.74	0.78	1.33	2.59	0.33	55	30	27	29
UMC	25%	2.25	0.68	1.23	2.40	0.33	42	20	27	25
	50	2.32	0.68	1.17	2.22	0.32	50	23	25	25
	75	2.25	0.67	1.18	2.41	0.31	63	34	26	25
LSD (5% level)		NS[z]	0.10	NS	0.35	NS	NS	9	NS	NS

[z] Not significantly different.

Regardless of the medium treatment, there was no apparent symptoms due to specific nutrient toxicity or deficiency. Leaf analysis for dogwood indicated only small to moderate increases in leaf P, Ca, Mn, and(or) Zn in some or all treatments with compost (Table 3); there was no effect of mushroom compost on leaf N, K, Mg, Fe, and B. Similar results were observed in forsythia (data not shown).

Soluble salt levels and pH of the two sources of mushroom compost increased with increasing proportions of compost, with values generally higher in the UMC than in the WMC (Table 1). While pH tended to rise over time, values for soluble salts showed the reverse trend. Except for the elevated value of 1,030 mhos $\times 10^{-5}$ at planting time and perhaps the value of 101 mhos $\times 10^{-5}$ in the 75% UMC treatment at harvest, all other values for soluble salts (Table 1) were not considered high enough to cause plant injury. This evidence suggests that salts were leached away rapidly by irrigation before manifestation of any detrimental effect. Also, the species used in the study may be quite tolerant to high salt levels. It is noteworthy that in a related observation trial, several plants of each of the two species in 100% UMC grew as well, if not better, than plants in the treatments described above. Another species, *Prunus* × *cistena*, also grew well in 100% UMC.

Rathier (8) indicated that mushroom compost in amounts up to 33% by volume can be useful as a partial substitute for topsoil or for peat moss in greenhouse crop production. According to the experience of flower growers, using a growing medium with more than 15% by volume of freshly spent mushroom compost can cause problems (2). Interestingly, in the present study, the increasing shrinkage and accumulation of excess total salts in media with high proportions of both UMC and WMC were not detrimental to growth but in fact were associated with increased dry matter yield. It was expected that treatments with high proportions of UMC would result in poor growth due to excessive salts. However, the increased growth (i.e. dry matter yield) with these treatments suggests that woody nursery stock may be more tolerant of high salts than herbaceous crops.

Presently in Ontario, several commercial nurseries routinely add weathered mushroom compost to container growing mix to culture nursery crops. To save in handling costs and time, it would be desirable to use mushroom compost for growing-on after little or no exposure to weathering and (or) leaching. However, until definitive research in the future indicates otherwise, dangers of high salt levels should be reduced by composting, leaching, and (or) by taking soil tests to determine when the material is suitable for use (8). Unweathered material should be used with care or avoided at this time.

Papermill Sludge. Best growth of spiraea in terms of height or top dry weight yield occurred in the secondary-amended medium (Table 4), although foliage of plants in this treatment had a dark blue-green sheen. In contrast, unacceptably poor growth occurred in Fraser-amended media. This appears to be related at least in part to excessive and low quantities of nitrogen present in the secondary and the Fraser mixture, respectively (Table 5). However analytical data of leaf N (Table 4) did not relate with this observation.

Table 4. Growth and leaf N, P, K content of spiraea grown in media amended with different types of papermill sludge.

Type	Sludge	Height (cm)	Top dry wt (g/plant)	Percent dry weight N	P	K
Bark (control)	0%	30.3	18.1	2.49	0.23	2.19
Primary	33	28.6	13.1	2.48	0.22	2.23
Secondary	33	35.3	39.2	2.55	0.22	1.95
Ontario mixture	33	30.8	22.5	2.58	0.22	2.04
Fraser mixture	33	22.8	5.1	2.91	0.22	1.91
LSD (1% level)		3.1	7.2	0.32	NS[z]	0.28

[z] *Not significantly different.*

Table 5. Initial N, P, and K content in representative samples of papermill sludge.

Type	Percent dry wt N	P	K
Primary	0.50	—[z]	0.24
Secondary	3.50	—	0.25
Ontario mixture	1.50	0.17	0.25
Fraser mixture	0.20	0.12	0.02

[z] Data not available.

Leaf analysis also indicated little or no differences in leaf N and K among the various types of sludges and did not reveal any imbalances in these major nutrients (Table 4). Increased growth with the secondary sludge may have diluted any increase in uptake or masked nutrient imbalances. Shrinkage was higher in all sludge-amended media than in the bark control (Table 2), but there was no apparent relationship between shrinkage and plant growth.

Further investigations are required to determine the influence of different proportions of each sludge in the media, the role of both macro- and micro-nutrients, and the effect of fertilizers added to types such as the Fraser mixture that is low in nitrogen.

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SPRING/SUMMER PROPAGATION AT JACKSON NURSERY

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Spring/summer propagation accounts for 90% of all propagation that takes place at Jackson Nursery. Cuttings are stuck in outdoor bottom-heated and unheated mist beds beginning the first of April. Needle evergreens are the first group of plants to be stuck, next are the softwoods. The softwoods are started approximately the end of May or the first of June and continued into August.

Semi-hardwood cuttings, i.e. rhododendron, begin mid-July and end in August. Direct sticking of cuttings of easy-to-root species was started the summer of 1986 as an experiment and is being continued today.

NEEDLE EVERGREENS

Taxus. Taxus cultivars are started the end of April and completed by the end of May or before new growth begins. Wood is collected from field-grown plants that were trimmed no later than June 15th of the previous year and have put on at least 7 to 10 in. of new growth. This is the wood that is used for cuttings taken the next year in April. New wood is collected, stripped, cut to a length of 7 in. in the field, put into bundles of 25, placed in poly bags, and then brought into the propagating room, dipped into Wood's rooting liquid, and checked for proper length and thickness. These cuttings are now ready to be stuck in the outdoor heated mist beds (1).

Juniper. Juniper cultivars are the next species to be done. They are handled much the same way as taxus. They are also stuck in heated mist beds. Once these cuttings are rooted, usually taking 7 to 10 weeks, they are potted into one gal. containers; this is a change from our normal production schedule of two years ago. We find by potting plants as soon as they are rooted, we have less chance of diseases in the cutting beds. Plants have ample time to develop a root system in the remaining growing season. The following year we obtain more growth from the rooted cuttings that are potted immediately after rooting than from those held in a cutting bed and potted in the spring.

Thuja. Thuja wood is collected in the field, stripped and cut to length much the same way as for other evergreens. After treatment with Wood's rooting liquid, they are stuck in an unheated bed. We find that heat is not necessary for this species. All watering is done by an intermittent mist system.

SOFTWOODS

Softwood cuttings are made in the field, placed in moistened poly bags, and brought to the propagation room to be checked and dipped in Wood's rooting liquid. These cuttings are stuck in a 3 ft deep cold frame that is covered with white poly. The reason we use a deep cold frame is for winter protection for plants that will not tolerate temperatures below 32°F. The use of microform blankets and sash made of filons have made it possible to maintain safe temperatures of 32°F even when outside temperatures go as low as −20°F. The poly is supported by hoops made of ¾ in. water pipe and placed at 3 ft intervals. The medium is sand and perlite (1:1, v/v). Intermittent mist is supplied by ¾ in. P.V.C. pipe and controlled by two time clocks.

SEMI-HARDWOOD

Rhododendron propagation begins when the color of the stems starts to turn from light green to a darker green and the wood snaps when bent; this is usually around the middle to end of July. The wood is collected early in the morning, placed in plastic bags that have had water added and brought to the propagating room. We collect only the amount of wood that can be stuck that day. If we have more wood than needed, it is placed in a cooler at 40°F and can be used the next day.

At this stage the cuttings are washed with water from a garden hose with a coarse nozzle attached. We have found black vine weavil grubs in the propagating benches and by washing the cuttings we eliminate the eggs that have been layed by the adult. Cuttings are left to drain. The cuttings are made 3 in. long. leaving 3 leaves that are cut by ⅓ to give more room in the propagating benches. The base of each cutting is given a heavy wound into the cambium layer on one side approximately 1 in. long. They are dipped in a mixture of Benlate and Hormex 45 (1:9, v/v) for some cultivars and different dilutions of Wood's rooting liquid for others.

Cuttings are stuck in a medium of Canadian peat and coarse perlite (1:1, v/v). When overnight temperatures begin to drop, around the first of September, bottom heat is provided to keep an even temperature of 70°F. Water is provided by an intermittent mist system controlled by a homemade "leaf". This leaf unit is made of a threaded brass rod with a piece of 6 × 6 in. screen on one end and several nuts on the other end (a mercury switch is taped to the rod). When the screen collects water, it drops a few inches and the mercury rolls away from the contacts and the water shuts off. When water evaporates, the nuts on the other end act as a counter weight and the nuts drop, causing the mercury to roll back to the contacts and the 24 volt solenoid value to open.

After cuttings have rooted, usually late October to early November, they are taken to a polyhouse where they are planted in raised benches in a medium of peat and perlite (1:1, v/v). They are given a liquid feed of Peters 20-20-20 at the rate of 200 ppm and this is repeated in 10 days. Temperature is maintained at 32 to 34°F until March 1st when the temperature is increased to 65°F. Liquid fertilizer is then applied on a regular schedule every 10 days to two weeks (2).

DIRECT STICKING

Direct sticking was started as an experiment during the summer of 1986. This method of producing plants is not new and is being used in Europe as well as in the United States. We began by filling one-gal. containers with our regular potting mix of ⅓ Canada peat, ⅓ rotted pine bark, ⅓ sharp sand (pH adjusted to 5.5 to 6); no other amendments were added at this time. Containers were filled and placed in a 14 × 96 ft. hoop house, arranged to provide easy access for sticking cuttings by having two walks instead of one. White poly was used and fastened down to cover the hoops.

Propagation wood was collected, prepared and treated with Wood's rooting liquid and stuck into the medium. Two cuttings were used per pot. If adequate wood was available, three cuttings would be used, for this seemed to make a sellable unit sooner. Water was provided by overhead pipe and nozzles, 1 in. P.V.C. pipe was used with L10..LA. Rain Bird nozzles spaced 10 ft. on center. This was controlled by our homemade "leaf." Water was allowed to run from 8 a.m. until 7 p.m. when cuttings were first stuck in early June and was decreased as the days became shorter.

Easy-to-root species have been used so far. Plants that withstand large amounts of water are stuck first, like potentilla. Other species that have been successfully propagated using this method are: *Euonymus fortunei* 'Colorata', *Hedera helix, Cotoneaster horizontalis, C. adpressus* var. *praecox, Berberis thunbergii* 'Atropurpurea Nana' [syn. 'Crimson Pygmy'] and *Cytisus* × *praecox*.

Fertilizer is applied in the form of Osmocote (14:14:14) 3 to 4 months formulation at the rate of 2.5 grams once rooting has taken place. More fertilizer may be necessary but testing has to be done before any conclusion can be made.

The containers of the rooted plant material remain in this polyhouse until it is moved to a growing area the next year. The advantage to direct sticking in one gal. containers is that plant roots are not disturbed for two years, resulting in a sellable plant sooner (less handling of plants because plants remain in the same house for one year).

The disadvantages are more cutting wood is needed, more space is needed, and more time is spent on the propagating stage.

LITERATURE CITED

Gouveia, R. J. 1984. Rooting cuttings in outdoor mist beds. *Proc. Inter. Plant Prop. Soc.* 34:537–539.

RALPH SHUGERT: Bob, what is your hormone treatment?

BOB GOUVEIA: For *Taxus* we use Wood's rooting hormone, diluted 5:1 (v/v); with more difficult-to-root species, 3:1 (v/v), and for softwood types a 20:1 (v/v).

CLAYTON FULLER: You need to watch slow-release fertilizers use because you can get a salt build-up with some formulations.

Tuesday Afternoon, December 8, 1987

The afternoon session was convened at 1:50 p.m. with Bruce Macdonald serving as moderator.

MODERN FERTILCIDE IN THE NURSERY

CLAYTON W. FULLER

Bigelow Nurseries, Inc.
Northboro, Massachusetts 01532

What is fertilcide? It is the process in which the manufacturer uses a blended fertilizer (in this report it will be 10-10-10) and coats it with a herbicide. In this paper we will only refer to herbicides by their common trade names. The herbicides being used at present for the process and which we will discuss are Dual, Goal, Kerb, Simizine, and Surflan. The blending of these products is covered by EPA Form 3540-16, "Pesticides Report for Pesticide-Producing Establishments". You should secure from your manufacturer a copy of this form and have it on file if you use any of these products.

Although the use of these blended products is not new to agribusiness (the amended EPA Form is dated 1980), they have not been in common use in the nursery industry—maybe due to unavailability.

When we first looked at this program in 1983 we were intrigued with the possibility of applying fertilizer and herbicide in one application. However, being a new program we were not sure it would work. At Bigelow Nurseries we interplant shrubs between rows of shade and ornamental trees and this raised a number of questions about the program. Would it be possible to apply this

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When we first looked at this program in 1983 we were intrigued with the possibility of applying fertilizer and herbicide in one application. However, being a new program we were not sure it would work. At Bigelow Nurseries we interplant shrubs between rows of shade and ornamental trees and this raised a number of questions about the program. Would it be possible to apply this material without damaging a sensitive plant in the middle of the block? Would we be able to control grasses and other weeds currently established? Working with the manufacturer and the company's herbicide consultant the answer seemed to be no, we could not expect to control all weeds without some damage to our crop, but we could control approximately 90% by using herbicides that would not be detrimental to the growth of the crop. The decision was made to go for the 90% control on a trial basis in selected fields. The trial results looked very promising so the program was expanded each year. We have not extended this program into fields in which the crop is within one or two years of market; there we are still using our old methods of control. The area in which the program has expanded is in new production fields. Following is the method by which we have implemented this program.

As in any good program, careful attention must be taken in the preparation of the land. The first step is applying 3 qt/A Round-Up plus a surfactant (your choice), to eradicate all vegetation thus eliminating future problems with hard-to-control weeds. Lime and fertilizer are applied and plowing and harrowing operations are completed. After the crop has been planted a cultivator is used to level the land between the rows. Then stones, if you have them (we are blessed with many), are removed and the fertilcide is applied at the rate of 400 lb/A.

METHOD OF APPLICATION

Application is made with a tractor and a three-point hitch spreader. Our spreader has an effective throw of 30 ft. Therefore care must be taken in lining out a field if it is interplanted, i.e., planning ahead so that the row you want to use for application isn't planted.

INCORPORATION

Follow the manufacturer's recommendations when applying herbicides.

1) Irrigation—Always is the best, if available

2) Rainfall—Watch the weather patterns, still a very good alternative, as many acres can be covered in a very short time with this method of application.

3) Cultivation—Shallow cultivation of 1 to 2 in. is still a good proven method of incorporation, although with some herbicides it is not recommended, i.e. Goal. We have not experienced any problems with incorporation. The only problem we have had with this method is if we are in a dry spell. Where we have cultivated there was excellent control, but in the plant row the control was less than desirable, thus requiring a spot spraying of an herbicide such as Round-Up for complete control.

TIMING OF APPLICATION

Spring. It is critical to follow the manufacturer's recommendation at this time of year. Applications ideally should be made before bud break, although some materials appear not to harm emerging growth and none we have used seem to harm mature growth. Goal is the only material that we have used that has damaged leaves in the formative stages to the extent the plant was defoliated. A June 6th application of Goal-Simizine was applied with rain predicted that evening. The day was cool and humid, turning to cold and snow by late afternoon. It is our understanding from the manufacturer that the active ingredient in Goal was not the culprit, but rather it is the carrier they use that has a very high volatility rate in cool or cold, high humidity, rain or snow conditions. It therefore should be applied 12 hr. before any of these conditions exist. We have not quite figured this all out yet. With more experience and proper timing we should eliminate this factor. Refoliation did occur and although no plants were killed because of this, die-back was observed on some of the new growing tips and growth for the season was about one third less than normal.

Fall. Application can be made after the plants are in complete dormancy, but before the ground has frozen. Incorporations methods are the same, although in our region at this time of year (November) we seem to have enough cloudy and rainy periods to complete the application and let rainfall do our incorporation. It has been our experience that some frost in the ground is not detrimental. Freezing and thawing tends to help incorporate the material.

Summer No applications have been made as we feel that with pruning there always is new bud break and varying stages of leaf growth.

Controlling the vagrants. Much has been said and written, we suppose, about having a completely weed-free nursery; but knowing this to be more fiction than fact a good program must be in hand to control any weeds from entering our fields and destroying our fertilcide program. This program can be implemented as we have with knapsack sprayers and a tractor-mounted sprayer using Paraquat for annuals or Round-Up for perennials with very little labor and expense. Hairy vetch is the only problem weed we have and it can be controlled by the above-mentioned method.

Check Plot. A check plot was left to observe the results. The untreated area after a fall application was found to have a 100% population and the treated area a 1% population of grasses and other weeds.

Band treatment and ground covers. Being good shepards of the land and realizing we do not want to destroy our land so it won't grow our next crop, we were interested to see if the rate of herbicide we are applying would inhibit our winter ground cover. We have planted oats and winter rye between our rows with much success. Because of increasing interest in finding the ideal ground cover for use between tree rows for soil and erosion control, we are looking at methods of applying the herbicide as a band treatment. While banding will increase the cost of application, the increased cost may be offset by the lower cost of material purchased.

Cost of application. In preparing the costs per acre of purchasing and applying these materials, consideration has been given to the fact that we have fields in many locations (Table 1). Therefore costs include equipment, moving, tractors, and travel time to and from these locations are included in the application cost.

Table 1. Costs for application of selected fertilizer and herbicide combinations.

Treatment	Cost ($)
400 lbs 10-10-10—1.25 lb Simizine-2 lb Surflan Tech per acre:	$114.50
400 lbs 10-10-10—1.25 lb Goal-2 lb Simizine Tech per acre:	$134.50
400 lbs 10-10-10—1.25 lb Goal-3 lb Dual Tech per acre:	$124.50
400 lbs 10-10-10—1.25 lb Goal Tech per acre:	$119.50
Round-Up of Vagrants—per year	$ 46.00

Combinations of herbicides were used in all but one application for good control of grasses and other weeds. Goal was used as a single herbicide where we had a sensitive plant, i.e. *Tsuga*, and they had been previously treated with a combination herbicide. **Please read carefully.** These blended materials do not have a long storage life. According to our manufacturer they should be used within 4 to 6 weeks of blending for maximum effectiveness. If possible we try not to use the same combinations in the same fields with each application, thus eliminating the possibility of a single herbicide buildup. Our experience at present indicates that with this program we will be able to completely skip a season of herbicides in some and maybe all fields. We have a 12 acre field under trial this year treated only with controlling the vagrant method and the results are very promising.

CONCLUSIONS

Why did we consider fertilcides? Economics and labor are certainly a prime factor. Within our organization one man and one tractor with spreader can apply the entire fertilization and herbicide program in most fields in a single effort, thus eliminating the need for any other equipment or personnel for this all-important job in the hectic spring and fall seasons. Delegating this program to one person should almost assure the project will be completed on time rather than having to steal people from one job or another to get the job done. Eliminating grasses and other weeds from our fields means no host plants for diseases and pests, cuts the cost and applications of pesticides allowing us to go to an IPM spraying program, eliminates trash for rodents to live and breed in, cuts our cost for rodenticides, lessens competition for available water, lessens the pressure of irrigation, and last—but first—a non-competitive environment for our plants to grow and flourish in and maybe make the market one year earlier and possibly increasing our profit.

In the spring of 1988 we are going to test a small area of our container operation for this type of program.

RALPH SHUGERT: In Western Michigan Dual has not knocked out yellow nutsedge as you have reported.

SOLVING DRAINAGE PROBLEMS ASSOCIATED WITH AUTOMATIC IRRIGATION SYSTEMS

CHARLES A. HILDEBRANT

Hildebrant Nurseries
Oldwick, New Jersey 08858

The modern nursery has faced cost controls in many ways. One of these has been to install automatic irrigation systems in areas used for container production. Whether the automatic system is drip, or overhead spray there is, in varying degrees, waste in the form of run-off. Without a doubt the worst offenders are the various overhead spray systems. They put as much water on the area between the containers as they put in the containers. No great amount of time need be spent around a nursery to see that serious drainage problems quickly build up near irrigation systems.

There are, it turns out, two related problems with this waste water. The first problem is most readily apparent in the form of the surplus water running across the surface of the ground or puddling in the low spots. Through proper grading of the surface the puddling can be eliminated, and the flow can be channeled into areas where its presence can be more easily accepted. The second problem is much more difficult to solve. As the waste water lands on the ground from the sprinklers, or emerges from a pot, it proceeds to run off, following the natural grading of the bed surface. During the process a fair amount is absorbed by the soil itself, or whatever material is being used as the growing surface. Absorption occurs to even a greater degree in the areas where the water has been channeled after it leaves the bed area. The very obvious and, unforapplications of pesticides allowing us to go to an IPM spraying program, eliminates trash for rodents to live and breed in, cuts our cost for rodenticides, lessens competition for available water, lessens the pressure of irrigation, and last—but first—a non-competitive environment for our plants to grow and flourish in and maybe make the market one year earlier and possibly increasing our profit.

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Through the years we have used many different methods to deal with both of these problems, either together or independently. Difficulty and drawbacks were encountered in many of the various attempts and many methods discarded. The temptation when you encounter a spongy bed surface is to elevate the beds. This unfortunately shifts the water to the intermediate aisles or roads, which in turn become mushy. Elevating the beds does not solve the water absorption problem by the bed surface. They still are difficult to get equipment on when you need to drive on the bed surface. Simply putting stone or plastic down on the surface seems only to mask the problem temporarily, only to have it reappear later.

We are a medium-sized nursery with little land to spare. We need to have a maximum use of our available production area. This requires us to keep our growing beds constantly in use. We use the areas between the beds as our roadways and paths to move plants in and out. In our retail areas these paths between the beds are where customers walk. Therefore the conventional wisdom of grading the beds to drain into the intermediate paths became unacceptable to our application.

Large amounts of mental concentration were not necessary to arrive at the next logical step in drainage water handling. This was to install perforated pipe underground to leach this surplus water away from the surface and carry it to a distant discharge point. After installing several of these systems in various trial beds we quickly discovered that their design is not as simple as it would seem to be. Our first discovery was that by installing a drainage pipe through the bed area, this did not necessarily mean that you therefore dried up the bed surface (we used exclusively, corregated, perforated, black plastic drainage pipe). It turned out that the water was held within the soil by capillary action between the soil particles. This force acting on the water is actually stronger than the force of gravity. How strong the capillary action is, is a direct relation to how small the soil particles are. The smaller the soil particles, the more water is held in the soil. There is a tremendous difference in particle size and numbers in the common soil types.

We found that what was happening to our new underground drainage system was that so much water was being held in the soil by the capillary action that the system failed. We had drained the area immediately over and close to either side of the pipe, but as we went further away from the pipe it remained wet. Figure 1 shows what happened to the water level on our system.

Our soils change greatly from area to area in the nursery. We found that in coarse material, such as coarse sand or fine gravel, the water line projected outward from the level of the drainage pipe somewhat flatly. Where we were in a heavy silty clay or loam, how-

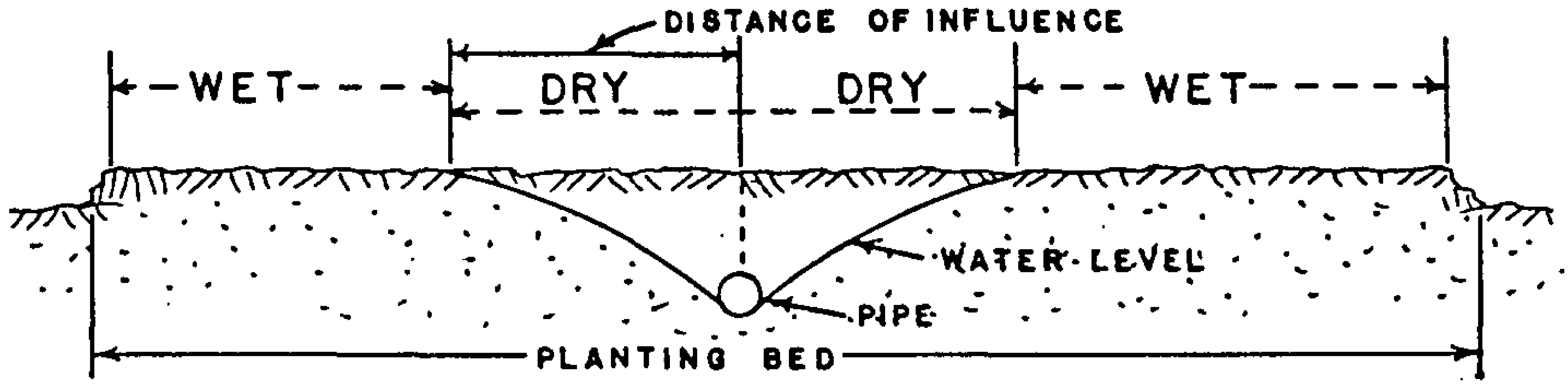

Figure 1. Water level characteristics after installation of a single drainage pipe.

ever, it rose very steeply and restricted the surface area that could effectively be drained by the pipe. By monitoring the soil water level at various distances from the drainage pipe; by placing the pipe at various depths; and by trying this in several types of soil, a chart was developed to give a guideline of the drawdown capability of the drainage pipe. Table 1 gives a guideline as to the distance from a given pipe, at a given depth, that the water line will reach back up to its original height. Beyond the stated distance on the chart the pipe will have no influence, the ground surface will remain wet. The chart is based on level ground conditions.

Table 1. Drainage pipe distance of influence[1].

Pipe	Soil types and distance of influence (ft)				
depth (ft)	Silt/clay	Very fine sand	Fine sand	Medium sand	Coarse sand
1	2	4	8	15	28
2	4	8	15	30	
3	6	12	24		
4	8	16	32		
5	10	20	36		

[1] Meaning that distance either side of the drainage pipe that the water level is back at its original height.

EXAMPLE: If we wished to design a well-drained bed using the existing soil as the final surface, then:

GIVEN: Bed size needed—45 × 200 ft.
Soil type—very fine sand

DESIGN: From Table 2: for a pipe 2 ft deep in very fine sand we find that it will keep a dry surface for a distance of 8 ft on either side of the pipe (its distance of influence). Therefore a pipe will drain an area 16 ft wide. We will have to place three parallel pipes in our bed in order to come close enough to our desired 45 ft width. If this is done the water level configuration under the bed surface would appear something like Figure 2.

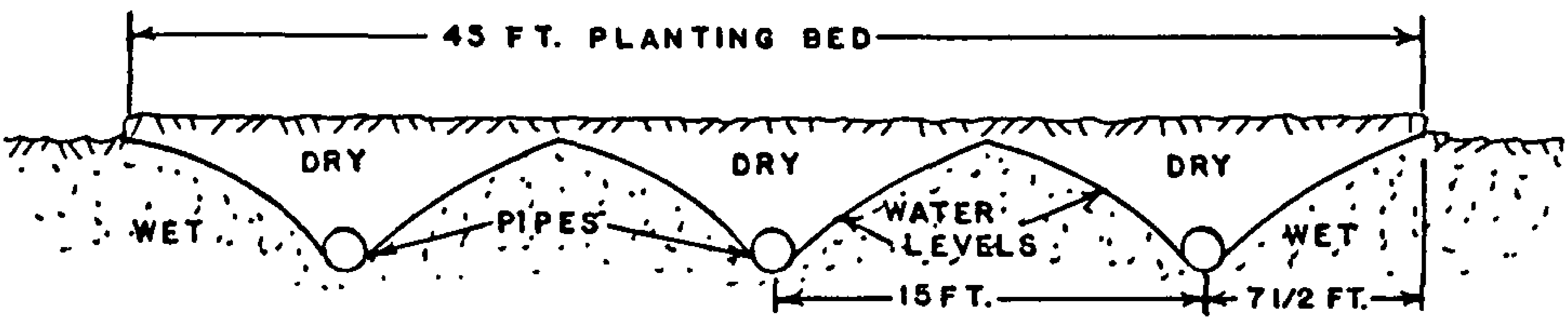

Figure 2. Water level configuration under the 45 × 200 ft. described in the text.

In designing underground drainage one must consider the capacity of the pipes to use. One should take the maximum number of gallons per minute of water to pump through the irrigation system and increase this amount by no less than one-third, to arrive at a figure to base the pipe size upon. If the natural ground water table is very high, and the piping must handle this water as well as the irrigation water, then one must consider this too when arriving at a pipe capacity figure. With this calculated one may look up the capacity of various sized pipes in Table 2.

Table 2. Flow capacity for corregated plastic pipe[1,2].

Pipe diameter (in.)	Flow[2](GPM)[3]
4	75
6	215
8	450
10	1250
12	1900

[1] Chart courtesy of US Soil Conservation Service.
[2] For pipe installed on a 1% pitch.
[3] Flow is based on a totally free discharge—no obstructions.

EXAMPLE: If we were to use our previous example of the 45 × 200 ft bed, and added to our given information that we wanted to irrigate this bed at a rate of 150 GPM, we add our safety factor of one-third of the irrigation flow (150 + 50), giving us 200 GPM. From Table 3 we see that we would need to use 4 in. diameter pipe. This is due to the fact that we will be using three pipelines (see previous example workup). Therefore each pipe will carry only one-third of the total flow or about 66 GPM. If the pipes were to be combined at the end of the bed into a single pipe to carry the water to the discharge point then this single pipe would have to be 6 in. in order to have the capacity to carry the flow of 200 GPM.

Some other strategies can also be employed to deal with the waste water underground if it is desired to not utilize the drainage characteristics of the existing soil. Should the soil be a clay or silt with demoralizing drainage characteristics, one probably would be better off not trying to percolate the water through it. Grading the surface of the bed to slope to the center (assuming a level bed) from both edges with a pipe in a trench at the middle, and covering the entire surface with 3 to 4 in. of stone works well (see Figure 3A). A modification of this, if the bed is on a slight slope, would be to have the pipe trench along the low side of the graded bed and have the water flow through the stone and down into the trench and pipe (see Figure 3B). The pipe trenches must be totally backfilled with stone. The best stone we found for the bed surface, from a water carrying standpoint, is clean ¾ in. crushed stone. This is without a doubt also the best stone to surround the pipes in the trenches. Finishing the bed surfaces with stone is very desirable, but it must be remembered that this can be costly as well. One ton of ¾ in. clean crushed stone, placed 3 to 4 in. deep (the desirable depth) will only cover 60 sq ft of bed surface.

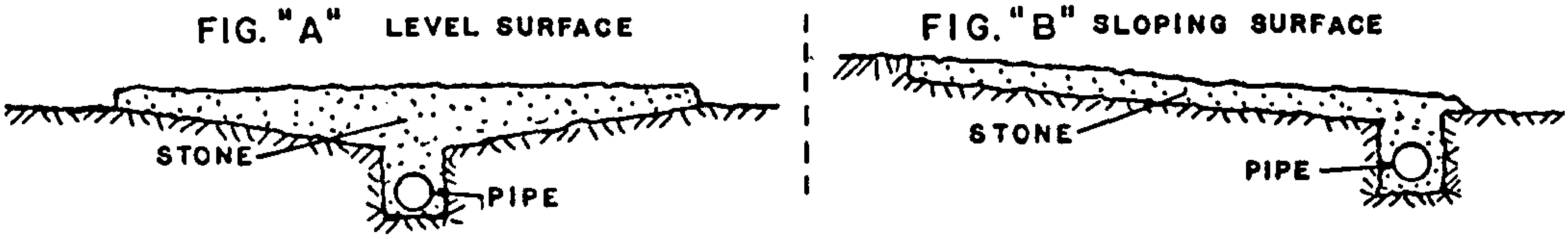

Figure 3. Grading configuration for level or sloping beds.

A very desirable thing to do if one is using the natural ground as the final surface, is to totally backfill the pipe trench with stone even though the stone may not be used for the bed surface. This will definitely increase the transmission of the ground water to the pipe. If, in the nature of the operation, there will tend to be a great deal of silt or organic matter traveling in the water, it is desirable to put a "filter" layer of 2 in. of 3/8 in. stone on top of the trench or bed surface. This filter layer, placed on top of the 3/4 in. stone, will trap the foreign matter and keep it from clogging the water flow ability of the larger stone. In extreme cases the 3/8 in. stone may have to be replaced periodically. Choose the surface on its inherent ability to transmit water. One cannot get soil with poor water carrying ability to move water to the pipes.

These systems have worked well for us. Properly done, they have taken us from mud holes to good, dry clean working surfaces in our nursery.

MICROPROPAGATION OF ASH (*FRAXINUS*)

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Abstract. Shoot tip explants from juvenile and adult green ash (*Fraxinus pennsylvanica*) and adult white ash (*F. americana*) formed callus and single shoots elongated in vitro. Consistent axillary shoot proliferation was not obtained. However, when new shoots that developed in vitro from juvenile white ash shoot tip explants were excised and placed into stationary liquid (1 cm deep) Woody Plant Medium (WPM) (4) with 5 or 10 mg·liter^{-1} benzyladenine (BA), axillary shoot proliferation occurred. These shoots could be rooted in vitro on WPM with 0.1 or 1.0 mg·liter^{-1} indole-3-butyric acid (IBA) and 10 g·liter^{-1} activated charcoal, or in moistened vermiculite with no plant growth regulators. Plantlets were acclimatized to the greenhouse and field. Green ash internodes produced callus in response to 2,4-dichlorophenoxyacetic acid (2,4-D). White ash seeds that were transversely cut in half germinated in vitro and callus grew from the cut cotyledons. Somatic embryos formed directly from these seedlings or from the callus, especially on a medium with BA and 2,4-D, both at 5μM.

Green and white ash are important trees in forestry and ornamental horticulture. These species are typically propagated by seeds, especially for use in forestry. Horticulturally, many ash clones, e.g. 'Marshall Seedless,' are propagated by budding. Efficient in vitro techniques could be a more rapid means of reproduction than graftage.

REVIEW OF LITERATURE

In vitro studies on ash have met with limited success. Walter and Skoog (6) developed a medium for callus growth from internodes or vascular cambial slices from *F. pennsylvanica*. They did not regenerate plants. Brown and Hicks (1) placed *F. americana* buds, from adult trees, in vitro and single shoots grew. Axillary shoot proliferation was not reported. Einset and Alexander (3) placed nodal explants from juvenile *F. pennsylvanica* in vitro and obtained outgrowth of unbranched monopodial axes.

In our clonal studies, we initiated experiments to attempt to obtain axillary shoot proliferation from juvenile and adult green and white ash. We then wanted to root the shoots and establish them in the greenhouse and field. In studies ultimately aimed towards tree improvement, we conducted experiments to obtain callus and adventitiously regenerated plants of these two ash species.

MATERIALS AND METHODS

Seedling ($\leq$ four years old) green and white ash stock plants were grown in pots with peat-lite medium (Promix BX) in the greenhouse at 25 ±5°C under night interruption (2200 to 0200 h) with high output cool white fluorescent lamps. Local adult white ash were 15 to 25 years old and green ash were 20 to 30 years old. White ash stump sprouts were from formally seed bearing trees (10 years old) that had been cut down at the soil line. White ash seed explants were from samaras collected from local trees.

Shoot tip explants were harvested as 3 to 5 cm softwood cuttings, defoliated and placed in a 0.5% NaClO solution with Tween 20 for 20 minutes (white ash) or 14 minutes (green ash) followed by three 5-minute rinses in sterile deionized water. White ash seeds were sterilized for 30 minutes in 1.05% NaClO plus Tween 20.

Shoot tip explants were cut to 2.5 cm long and were placed into 25 × 150 mm culture tubes containing Woody Plant Medium (WPM) (4) with 30g·liter^{-1} sucrose adjusted to pH 5.8 with 1N KOH or 1NHCl prior to the addition of 7 g·liter^{-1} Difco bacto agar (when used) and autoclaving. White ash seeds were cut in half transversely prior to being placed in vitro. Explants were transferred to fresh medium monthly. Cultures were incubated at 25 ±3°C with a 16 h photoperiod and a PPF of 40 μM·m^{-2}·s^{-1} provided by cool white fluorescent lamps.

During rooting studies, 2.5 cm axillary shoots were placed either onto agar solidified WPM with or without 10 g·liter^{-1} activated charcoal or into 120 ml glass jars (baby food) with 60 ml moist vermiculite. When at least 75% of the shoots rooted, the lids were removed from the culture tubes or glass jars for five days. Plantlets were then removed from the vessels, dipped into deionized water and planted into 10 cm standard plastic pots with peat-lite medium (Promix BX). They remained in the laboratory for 5 more days and were then moved to the greenhouse. At this time 10 to 15 granules of Osmocote (14-14-14, N-P_2O_5-K_2O) were added to each pot. After 5 months in the greenhouse, plants were transplanted to the field.

RESULTS AND DISCUSSION

During the first five months on agar solidified WPM juvenile shoot tip explants from both species elongated, but did not branch. Callus grew at the cut shoot bases and was greatest on medium with BA and IBA, both at 1.0 mg·liter^{-1} (Table 1). Unexpectedly, during this time, white ash shoot tips exposed to auxin in vitro produced adventitious roots. The highest rooting was 51% after three months. These rooted cuttings were easy to establish in pots in the greenhouse.

Quiescent shoots (30 cm long) from adult green and white ash trees were collected during January, February, and March and placed into containers with deionized water. The water was changed daily. New softwood shoots were excised as explants. Green ash quiescent stems forced better in the deionized water than white ash, yielding 51.6% (54 of 125) stems with shoot growth ≥ 2.0

cm compared to only 15.9% (20 of 150) stems for white ash. In vitro, callus grew from the cut stems exposed to high levels of BA (Table 2), but only a few shoots elongated. Actively growing stump sprouts proved to be poor explant sources because 80% became contaminated within two weeks. Thus adult ash responds more poorly in vitro than juvenile stem explants.

Table 1. The influence of BA and IBA on shoot elongation and callus formation on shoot-tip explants of green ash.[z]

Growth regulators		Time					
		Month 1		Month 2		Month 3	
BA	IBA	Callus rating[y]	Shoot elongation (cm)	Callus rating	Shoot elongation (cm)	Callus rating	Shoot elongation (cm)
(mg·liter⁻¹)							
0.5	0	2.1	1.3	2.1	2.0	2.1	2.2
	1.0	2.1	1.1	2.4	2.0	2.2	2.2
1.0	0	2.1	1.1	2.2	2.5	2.0	2.0
	1.0	2.4	1.4	3.0	2.0	2.8	3.5
	SE	0.08	0.22	0.17	0.51	0.11	0.61
		NS	*	NS	NS	**	NS
		Month 4				Month 5	
0.5	0	2.1	2.6			2.1	2.6
	1.0	2.5	2.7			2.9	2.6
1.0	0	2.1	2.4			2.1	2.6
	1.0	3.6	2.7			4.1	2.7
	SE	0.19	0.15			0.17	0.11
		**	NS			**	NS

[z] Each number presents the mean of 16 to 25 replications.
[y] Callus rating 1 = no callus, 2 = 1 cm diameter callus, 3 = 2 cm diameter callus, 4 = 3–4 cm diameter callus, 5 = > 5 cm callus.
*, **, NS: Indicates a significant interaction between BA and IBA at the 5% level (*), the 1% level (**), or non-significant (NS) according to F-test with 1 and 74 d.f.

Table 2. Callus measurements from adult white and green ash shoot tip explants after nine months in vitro.

BA concentration mg·liter⁻¹	white ash		green ash	
	Callus diameter (cm)	Total dry weight (mg)	Callus diameter	Total dry weight
5	1.28	233.6	1.12	225.1
10	1.79*	318.2*	1.77**	332.7**
15	1.87**	355.6**	1.94**	387.6**
20	1.98**	395.7**	2.10**	397.1**
5% LSD	0.40	71.96	0.42	53.20
1% LSD	0.55	99.16	0.57	57.00

F-tests for callus diameter and dry weight of inocula were significant at the 1% level.
*,**Significantly different from 5 mg 1^{-1} BA at the 5% (*) and 1% (**) level, respectively.

After juvenile shoot explants had grown 4 to 6 cm in length, the terminal 2.5 cm was excised and placed into stationary liquid or agar solidified medium. Consistent axillary shoot proliferation only occurred on white ash shoots on liquid WPM with 5 or 10 mg·liter^{-1} BA, with 10 mg·liter^{-1} being better (Table 3 and Figure 1-left). Green ash was not responsive.

Table 3. The influence of BA on axillary shoot proliferation of white ash in liquid medium.[w]

	Time after subcultering									
	1 Month		2 Months		3 Months		4 Months		5 Months	
BA mg·liter^{-1}	Mean[x]	Max.[y] Shoot	Mean	Max. Shoot	Mean	Max. Shoot	Mean	Max. Shoot	Mean	Max. Shoot
5	0.3	2	0.5	4	1.6	8	0.8	5	2.1	6
10	0.7	4	1.4	6	1.9	8	2.2	8	2.8	6
Minimum harvest[z]		4		24		36		36		

[w] New shoot growth was excised from the original explants and placed into liquid medium for up to 5 months.
[x] Each number represents the mean of 18 to 31 replications.
[y] This is the maximum number of shoots that were observed in an individual culture vessel at that time.
[z] Upon each monthly transfer, shoots were harvested for rooting studies. Only the most uniform were used, the remainder were discarded. The minimum harvest is the number of the shoots that were used. These were not counted the following month.

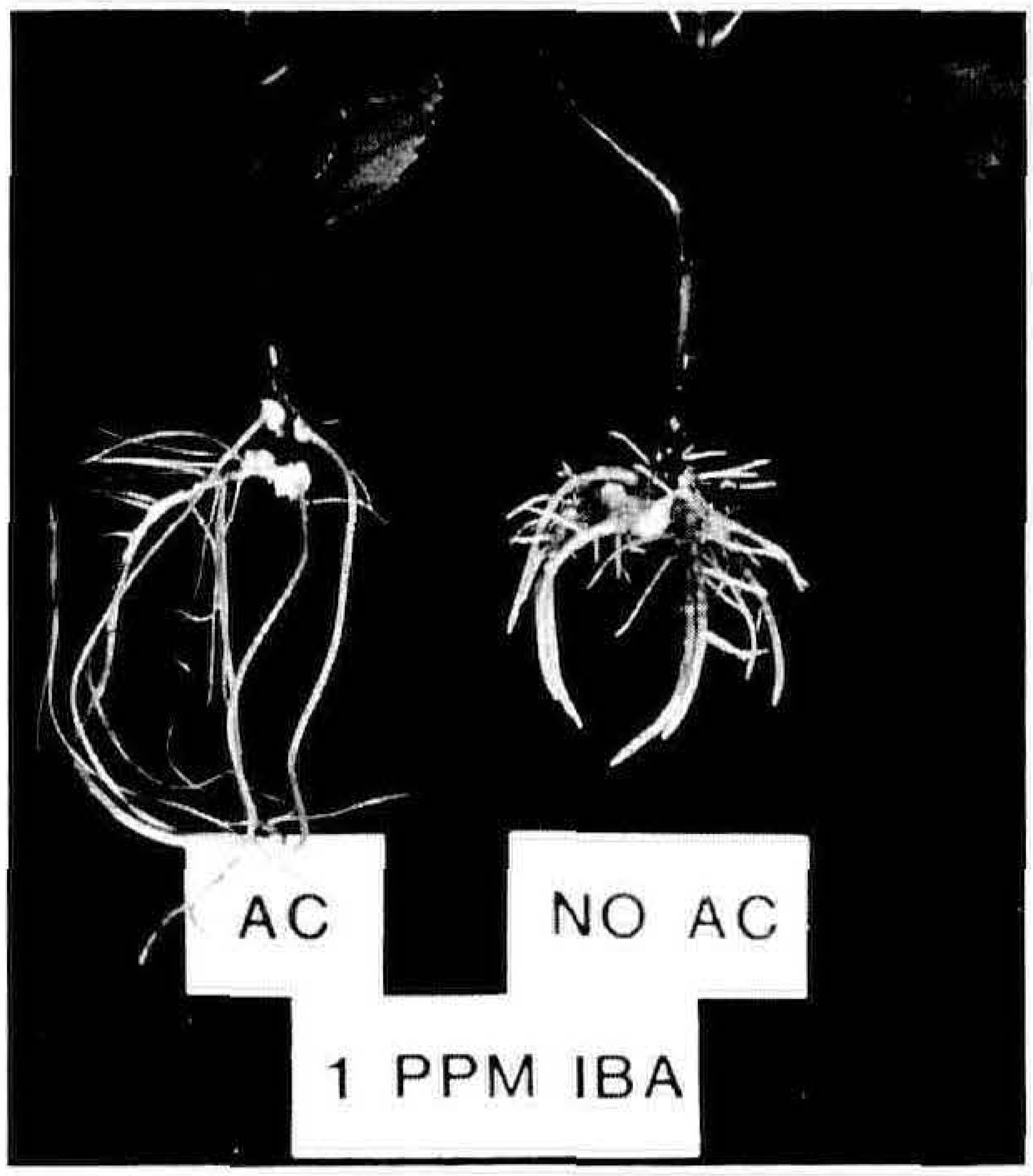

Figure 1. White ash. *Left:* Shoot multiplication from shoot tip explant on liquid medium. *Right:* Root quality was better on microshoots when activated charcoal (AC) was incorporated into the medium.

Because axillary shoot proliferation only occurred on juvenile white ash, these were the only shoots used in rooting studies. Best rooting was achieved on agar solidified medium with 0.1 or 1.0 mg·liter^{-1} IBA, however these roots were shorter and more brittle than those that formed on microcuttings with no auxin. When activated charcoal was incorporated into the agar solidified medium with IBA, rooting percentage remained high (up to 89%), and the roots were not stunted (Figure 1-right). Rooting of white ash microshoots was 100% using sterilized vermiculite and no plant growth regulators. Rooting occurred within one month.

Following a slow acclimatization process, 100% of the rooted shoots survived in the greenhouse after one month. Initially the plantlets produced simple leaves, but after approximately one month, they produced compound leaves. Plants lined out into the field had 100% survival.

In an attempt to produce callus, 1 cm long softwood internodes from juvenile green ash were placed on various media with either 1 or 10μM 2,4-D for 8 weeks (primary media). They were then transferred to secondary media for four weeks with either no plant growth regulators or with BA plus naphthaleneacetic acid (NAA), both at 0.5 μM. Callus production was greater with 1 μM than 10 μM 2,4-D, regardless of the nutrient salt formulation, and on MS salts, regardless of the 2,4-D concentration (Table 4). No plantlets regenerated from the green ash callus.

Table 4. The influence of 2,4-D and nutrient media in the primary media on the growth of green ash callus on the secondary media after 4 weeks.[x]

2,4-D (μM)	Fresh weight (mg)	Dry weight (mg)
1	1519.2	194.0
10	882.4	108.4
	**	**
Nutrient medium	**Fresh weight (mg)**	**Dry weight (mg)**
MS (5)	1750.7 a[y]	181.9 a
WPM (4)	1118.3 b	150.0 ab
DKW (2)	1019.5 b	142.9 b
WS (6)	915.5 b	132.0 b
	**	*

[x] Each number represents the mean of 79 to 80 (2,4-D) and 39 to 40 (nutrient medium) replications, respectively.
[y] Means followed by the same letter are not significantly different using Duncan's new multiple range test for alpha = 0.05 level.
*,**: indicate significance at the 5% (*) and 1% (**) levels according to F-test with 1 and 142 (2,4-D) and 3 and 142 (nutrient medium) d.f., respectively.

Cut white ash seeds that had been placed in vitro germinated and callus grew where the cotyledons touched the agar solidified MS or DKW medium. Directly from the explant itself and from the callus, somatic embryos formed (Figure 2-left). The highest percent embryogenesis occurred when BA and 2,4-D, both at 5 μM, were incorporated into the primary medium for 4 to 6 weeks.

The somatic embryos were variable and had from one to several cotyleons. They elongated (Figure 2-left-below) then some germinated into plants (Figure 2-right).

Techniques, such as somatic embryogenesis from callus and clonal micropropagation from juvenile explants, as described herein, might be utilized to improve important tree species, such as ash.

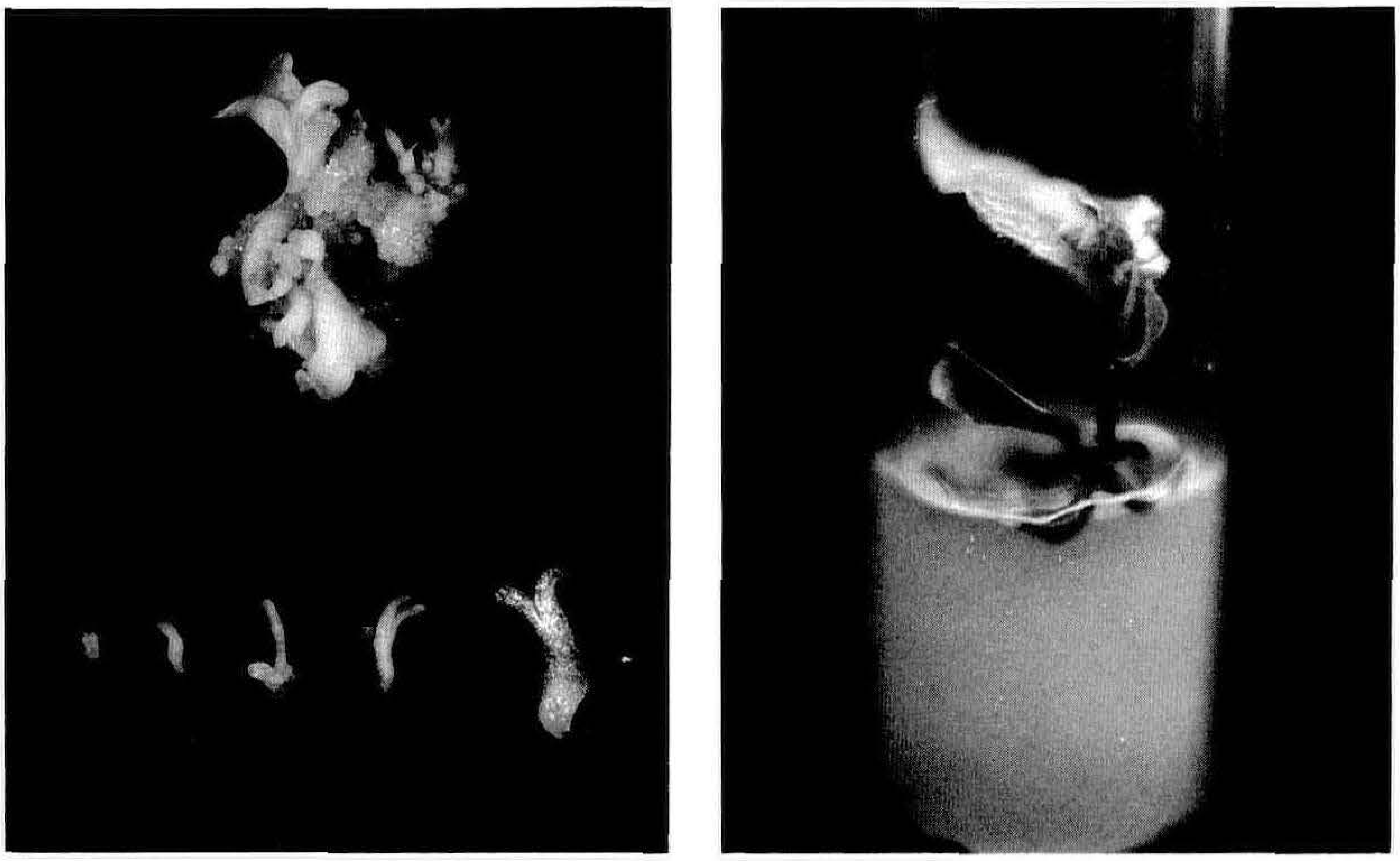

Figure 2. White ash. *Left above:* Somatic embryogenesis from cotyledon derived callus. *Left below:* Somatic embryos were variable and grew at different rates. *Right:* Some somatic embryos germinated and grew into plants.

Table 5. The influence of culture period on the primary and secondary media and plant growth regulators on embryogenesis from cut white ash seeds after 10 weeks in vitro.

Culture period		Primary medium[y]		
Primary medium (week)	Secondary medium (week)	Plant growth regulator BA (μM)	2,4-D (μM)	Percent embryogenesis[x]
4	6	0	0.5	2.6
		5	5	16.7
6	4	0	0.5	2.6
		5	5	13.0

[x] Each number is based on 76 to 80 replications.
[y] The primary medium consisted of DKW salts and the secondary medium is averaged across MS and DKW salts.

Acknowledgement. We thank Mrs. Lisa Hartline for assistance in preparing the manuscript.

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OLIVINE: A POTENTIAL SLOW-RELEASE MAGNESIUM SOURCE FOR NURSERIES

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Magnesium is essential for plant growth. About 10% of the magnesium in green plants is in the pigment chlorophyll which gives plants their green color as well as their ability to change light energy to chemical energy through the process of photosynthesis. The remainder of magnesium in a plant has many uses. High concentrations of magnesium are usually found in parts of plants where lots of energy is required such as the growing tips of roots and shoots or areas where seeds are being formed.

MAGNESIUM DEFICIENCY

The need for magnesium in higher amounts in these areas of rapid growth helps to explain why magnesium deficiency symptoms appear as they do. Magnesium moves readily from one area inside a plant to another. If there is not enough magnesium for all parts of the plant when conditions are right for rapid shoot growth or a heavy seed set is occurring, the magnesium will be preferentially transported to areas where it is needed most. When this happens, the older leaves on plants turn yellow because the magnesium needed for the rapid shoot growth or a heavy seed set is

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MAGNESIUM DEFICIENCY

The need for magnesium in higher amounts in these areas of rapid growth helps to explain why magnesium deficiency symptoms appear as they do. Magnesium moves readily from one area inside a plant to another. If there is not enough magnesium for all parts of the plant when conditions are right for rapid shoot growth or a heavy seed set is occurring, the magnesium will be preferentially transported to areas where it is needed most. When this happens, the older leaves on plants turn yellow because the magnesium needed for the rapid shoot growth or a heavy seed set is occurring, the magnesium will be preferentially transported to areas where it is needed most. When this happens, the older leaves on plants turn yellow because the magnesium needed for the green pigment chlorophyll was moved elsewhere. This also helps explain why male holly or podocarpus plants remain green while adjacent female plants with a heavy seed crop turn yellow. The extra drain on the limited amount of magnesium present due to seed production has used most of the magnesium required to maintain the green color in leaves.

Magnesium deficiency can be caused by a lack of magnesium or an imbalance in the proportion of magnesium to some other nutrients. The offending nutrient in most cases where adequate magnesium is present in Western North Carolina soil but is not getting into the plant is calcium. It is not uncommon for us to see a calcium to magnesium ratio of 10 or 15 to 1 in soils that have been limed with high calcium limestone. A more desirable ratio for most plants being grown in the mountain soils of North Carolina would be 3 or 4 to 1. Ammonium and potassium are reported to have an even greater influence on available magnesium. However, these nutrients commonly are not applied in high quantities on mountain soils although on some sandier soils high potassium fertilization has caused magnesium deficiency symptoms to appear.

In the soilless media commonly used for container production, calcium and magnesium are provided by mixing ground dolomitic limestone with the potting media. Eventually this can lead to magnesium deficiency even though the calcium to magnesium ratio in the dolomitic limestone we are using is about 2 to 1. The reason for this is two fold: 1) Magnesium carbonate is more soluble than calcium carbonate; and 2) Irrigation water in some parts of the U.S. contains significant amounts of calcium but little or no magnesium. Therefore, with the great amounts of water used to irrigate container grown plants, the magnesium in the limestone is dissolved and either used or washed away faster than calcium. This helps to explain magnesium deficiency in some container-grown junipers and photinia following a long hot summer.

Correcting Magnesium Deficiency Probably the best and most common way to prevent magnesium deficiency from ever occurring is to have the soil tested before planting, then lime with dolomitic limestone. Dolomitic limestone is also the best bet in containers where the crop permits incorporating relatively high rates or top dressing late in the season.

However, under certain circumstances dolomitic limestone cannot be used. In the North Carolina mountains, many of our crops will not grow well at the elevated soil pH that results when the tons of dolomitic limestone needed to supply calcium and magnesium to our soils are added. To supply needed calcium without raising soil pH too high, gypsum (calcium sulfate) is used. Generally one gypsum application pre-plant incorporated will provide the necessary calcium for a 3 or 4 year crop cycle. Longer duration crops like Fraser fir will need a top dressing of gypsum every few years.

However, using gypsum instead of dolomitic limestone presents problems because there is no magnesium in gypsum. Magnesium must be supplied unless large amounts are already present in soils or deficiencies will occur when the calcium in gypsum becomes available to plant roots. Calcium and magnesium must be applied to maintain the proper balance or one will be come deficient in the plant.

Yellowing of older needles on field grown eastern hemlocks and Fraser fir often occurred in Western North Carolina either the year gypsum was applied or the next season. Research showed that spraying new shoot growth when it was 3 in. long and again when it was 6 in. long with an Epsom salts (magnesium sulfate) solution containing 4 lb of Epsom salts in 100 gal of water would raise tissue magnesium levels to 0.10 to 0.15 percent. This is the level needed to maintain acceptable growth and color during commercial production of eastern hemlock and Fraser fir. However, this technique requires spraying every year which means 8 to 10 extra trips to the field for magnesium fertilization on a crop of 6 ft hemlock. To avoid these extra trips to the field an inexpensive, dependable, slow-release source of magnesium was needed. That lead us to olivine.

OLIVINE

Olivine is a natural mineral consisting of a solid solution rich in magnesium ortho silicate (forsterite) and iron ortho silicate (fayalite). Major deposits of high quality olivine exist in the North Carolina mountains, Norway, and the state of Washington. This high quality olivine contains about 90% forsterite and 10% fayalite.

Olivine is a greenish gray sand with a hardness similar to silica sand but somewhat heavier. Like other natural minerals with a slow rate of decomposition or reaction, olivine must be crushed to reduce particle size and increase surface area in order to be useful for plant growth.

The current primary commercial uses for olivine are in sand blasting (olivine will not cause silicosis as happens with silica sand) and by foundrymen in producing nonferrous castings as well as iron, manganese, and stainless steel.

Field Tests. Our first large long term test with olivine was initiated when we encountered an established (3-2-2) crop of eastern hemlock growing in a Porters silt loam soil. Plants were yellowing, more severe in older needles, which is characteristic of magnesium deficiency. Magnesium deficiency was confirmed by tissue analysis while magnesium status in the soil was determined by a soil test.

Soil test (exchangeable) magnesium was less than 5% of the cation exchange capacity, a low soil test level, and tissue magnesium levels were below the 0.10% level considered to be the lower critical limit.

In April, 1983, plants were treated with 400 flour olivine applied in a 6 to 8 in. wide band around the trees at the following rates: 0, ½ or 1 oz. Mg/tree. This is 0, 2.63 and 5.23 oz. of olivine, respectively, per tree. (We calculate that our olivine is 19% magnesium). Eighteen plants per treatment with 3 replicates were employed. Tissue samples were collected from the most recently matured twigs, dried at 105°F and submitted to the North Carolina State University Department of Soil Science Analytical Service Lab for determination of tissue magnesium levels at the end of the 1983, 1984, and 1985 growing seasons. A control magnesium treatment was applied following current recommendations with the epsom salts spray mentioned earlier.

The results shown in Table 1 indicate that magnesium concentration in trees receiving no magnesium was below the desirable 0.10 to 0.15% at the end of the 1983 season and continued to decline. By the end of 1985, these plants were uniformly yellow and dropping needles.

Table 1. Foliar magnesium level in *Tsuga canadensis.*

Treatment	% Mg in tissue[1]		
(oz Mg/tree as olivine)	1983	1984	1985
0	0.08	0.07	0.06
½	0.10	0.09	0.08
1	0.12	0.13	0.15
Control[2]	0.10	0.12	0.12

[1] 0.10 to 0.15% Mg is desirable.
[2] 4 lb $MgSO_4$/100 gal sprayed annually.

One-half ounce of magnesium from 400 flour olivine raised the magnesium percentage to the desired level in 1983 but was not able to sustain this level. One ounce, however, not only raised tissue magnesium percent to well within the desired range, but also continued to provide magnesium such that tissue levels of magnesium increased throughout this test with no repeat application of olivine. The magnesium sulfate spray, applied annually, also raised tissue magnesium to acceptable levels.

Our success with hemlocks prompted us to work with Fraser fir. By comparison with our hemlock site, the Frazer fir site soil test magnesium was not quite as low, 9% of CEC, but still lower than preferred, and the trees were a little older (3-2-3). This study was expanded to include 200 and 400 flour olivine, SulPoMag (0-0-21, 11% Mg) and the standard Epsom salts spray. Our first tissue samples were taken in 1985 even though first treatment was in spring, 1984. This is because Fraser fir is much slower growing than Eastern hemlock with all new shoot growth ceasing by mid-summer each year. First year results are shown in Table 2.

Table 2. Foliar magnesium level in *Abies fraseri*.[1]

Source of Mg	Oz/tree	% Mg in tissue 1985
Check	0	0.08
Olivine 200	½	0.10
OLivine 200	1	0.10
Olivine 400	½	0.11
Olivine 400	1	0.12
SulPoMag	½	0.11
SulPoMag	1	0.10
$MgSO_4$ Spray	—	0.10

[1]0.10 to 0.15% Mg is desirable.

The 1985 results indicate that Olivine 200, Olivine 400, and SulPoMag are at least as effective as our annual Epsom salts sprays. The next few years should let us know how long a single treatment of olivine or SulPoMag will remain effective. Since considerable difference exists in the cost to treat an acre with these materials (Table 3), efficacy over the life of the crop is very important. In fairness to SulPoMag, other essential nutrients, potassium, and sulfur, are provided when SulPoMag is applied. If these are needed by the crop, SulPoMag may be more economically attractive.

Table 3. Cost to treat magnesium deficiency.

Source	Mg rate/tree, oz	$/acre[1]
Olivine 200	½	19.92
Olivine 200	1	39.91
Olivine 400	½	25.44
Olivine 400	1	50.98
SulPoMag	½	48.30
SulPoMag	1	96.60

[1]Plant population = 1700 trees/acre

DISCUSSION

These results suggest that olivine has potential as a long term slow-release source of magnesium. A reduction in annual labor costs by eliminating the need for Epsom salts sprays plus the relatively low materials costs for olivine are seen as advantages.

Work is continuing in looking at rates and particle size for olivine use in the field. Questions exist concerning technology for applying finely powdered olivine efficiently as well as how it will interact with other fertilizer materials if blending, pelletizing, etc. occurs.

A major potential use for olivine would seem to be in container production, particularly in warmer climates where long growing seasons and high water use are common. We are currently analyzing data from the 1987 growing season with *Photinia* × *fraseri*, compact Andorra juniper, and 'Hino Crimson' azalea as test subjects. Thanks to support from the Horticultural Research Institute, research into olivine's potential for the nursery industry will continue.

CHIP BUDDING OF MAGNOLIAS

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Chip budding is well suited for the propagation of magnolias because it allows great flexibility in the scheduling of propagation. It is often practiced as a bench grafting technique in winter, and again in late summer and early fall. It is also used for outdoor grafting in spring, and in mid-to-late summer. In reality, chip budding is possible throughout the growing season. Highly specialized facilities are not required. If a greenhouse is used, grafts can be placed on an open bench. Grafting cases are not needed.

As a technique, chip budding is simple, easy to learn, and yields a high percentage of successful grafts. Close matching of stock and scion diameters is not necessary, permitting flexibility in rootstock utilization. Callusing of chip buds is rapid, and the graft unions are strong. Growth from the scion is vigorous, strongly upright, and of good form, frequently branching the first season. While these positive inducements apply generally to many species of broadleaved plants, they apply particularly well to magnolias.

PROCEDURE

I chip bud predominately onto established rootstocks in containers in the greenhouse, from late January to early March. Rootstocks are brought into the greenhouse (60°F minimum temperature) in early January, and set on an open bench. The stocks are ready for grafting when the buds swell.

The steps in chip budding are as described by Howard (1) and Macdonald (2). I prefer to collect scionwood the same day as I will use it, but pre-cut, dormant scions can be successfully stored by refrigeration in damp sphagnum moss in polyethylene bags for at

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I chip bud predominately onto established rootstocks in containers in the greenhouse, from late January to early March. Rootstocks are brought into the greenhouse (60°F minimum temperature) in early January, and set on an open bench. The stocks are ready for grafting when the buds swell.

The steps in chip budding are as described by Howard (1) and Macdonald (2). I prefer to collect scionwood the same day as I will use it, but pre-cut, dormant scions can be successfully stored by refrigeration in damp sphagnum moss in polyethylene bags for at least 3 months. Advance collection and storage of fully dormant scions is necessary for any budding that will occur after buds outdoors have begun to swell.

In setting the bud chip in place, it is important that the cambial layers of stock and scion be aligned on at least one side. If, because of depth of cut or disparity between stock and scion diameters, the distance between the lines of exposed cambium on the stock is greater than that on the bud chip, it will only be possible to line up the cambia on one side. Alignment on both sides will shorten the time necessary for complete knitting of the graft, but alignment on one side is sufficient for union to occur.

For tying the grafts, ½ in. wide polyethylene tape has been recommended, and works well. Being unable to locate a local supplier of polyethylene tape, I have substituted one-half inch, .004 gauge vinyl tape (from A. M. Leonard, Piqua, Ohio) with satisfactory results. Parafilm "M" has also been tried, but does not bind the chip tightly enough to the stock.

At 60°F minimum temperature, magnolias callus quickly. Chip buds with cambia matched on both sides are often completely callused and ready for removal of ties within 10 days after budding. Those grafts that leave exposed part of the cut area of the stock must be left tied until callus totally covers this area and contacts the edge of the bud chip. The advantage of using a clear tie, of course, is that the progress of callusing can be checked periodically, without disturbing the tie.

Once callusing is complete, and the tie has been removed, all or part of the stock above the graft is cut away to force growth from the scion bud. The stock may be cut off directly above the graft, just as you would prune a stem above a bud to redirect growth. If the stock is straight above the graft, I prefer to cut it off 4 to 6 in. above the bud, removing any side shoots or foliage, as well as any subsequent sprouts. Then the growth from the scion is tied to the remaining stub for support and training. Normally, this will be all the training that is necessary. Scion growth is strong and vertical, and apical dominance soon asserts itself, so there is little problem with errant growth, competing leaders, or suckers, such as often follows grafting a scion with more than one bud. The stock stub can be removed in late summer or fall, by which time the graft will be very sturdy.

COMPATIBILITY AND ROOTSTOCK SELECTION

When grafting a cultivar or clone of magnolia, a safe choice for a rootstock is the same species. I know of no case of intraspecific graft incompatibility in the genus *Magnolia*, such as occurs in *Acer rubrum*. When grafting a hybrid between two species that differ in stature, the larger of the parental species is recommended as a rootstock, unless some restriction in size is desired. For example, *M. acuminata* is the preferred rootstock for its hybrids with *M. denudata* (e.g. 'Elizabeth,' 'Sundance,' and 'Yellow Garland').

Traditionally, seedlings of *M.* kobus and *M.* acuminata have been most often used as rootstocks for those magnolias which bloom prior to or along with leaf emergence. *Magnolia kobus* is a suitable rootstock for any of the early blooming magnolias which do not exceed it in vigor or ultimate size. *Magnolia* × *soulangiana* is also a good rootstock for these small and medium-size magnolias.

When the large Asian magnolia species such as *M. campbellii, M. sargentiana, M. sprengeri, M. dawsoniana*, or their hybrids, (e.g. *M.* × *veitchii; M.* Gresham hybrids), are grafted onto *M. kobus* or *M.* × *soulangiana,* the graft union becomes unsightly because the scion grows faster and larger than the stock. This is not a sign of incompatibility, as it does not lead to breakage or other failure of the union, but it does detract from the appearance of the tree. Even when the larger-growing *M. acuminata* is used as the stock, its girth lags behind that of the scion because of its slower growth rate. During my employment at the University of British Columbia Botanical Garden, I found that seedlings of *M. sprengeri* 'Diva' make excellent, comparably vigorous, rootstocks for the large Asian species and their hybrids, and are preferable to *M. acuminata* where they are hardy (U.S.D.A. Zone 6b). *Magnolia sprengeri* seedlings are not available commercially, but can easily be grown from seed to budding size in one season, if grown in a ½ gal. milk carton or container of similar dimensions, filled with a well-aerated medium. First-year growth of magnolia seedlings is severely restricted in containers less than 6 in. deep.

For those species of magnolia which bloom after their foliage is fully expanded, many stock and scion combinations remain to be tried. In my experience, *M. hypoleuca* [syn. *M. obovata*] is compatible as a rootstock for the following: *M. fraseri, M. officinalis, M. sieboldii,* and *M.* × *wieseneri* [syn. *M.* × *watsonii*].

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STATE AND FEDERAL NURSERY INSPECTION: BANE OR BOON?

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My dictionary defines "bane" as a cause of destruction or ruin and "boon" as something that is beneficial or a blessing. How do you look upon the nursery inspectors who come to your nursery? Do you look upon them as intruders and unwanted guests—a bane, or as friendly, helpful persons—a boon?

During my 27 years on the staff of the American Association of Nurserymen I maintained contact with the state and federal nursery inspection agencies. During that time I observed many changes in both the nursery industry and the inspection services. Now as I look back I have to conclude the nursery industry and the general public is not benefiting as much as either should from the state and federal plant inspection services. Too many nurseries tolerate the plant inspection regulations and do not really try to understand what the system can do for them. Unfortunately, a few nurseries are uncooperative or outright antagonistic. These few give the whole nursery industry a black eye. And lest you think I am unjustly placing the full responsibility on the nursery industry, there is opportunity for improvement on both sides. However, the nursery industry is the one that stands to gain the most by modifying this situation. My objective today is to give you background on state and federal plant inspection services and outline some things that each of us can do to improve.

First let us all accept the fact that nursery inspection regulations are here to stay and that there can be valuable benefits to the industry from them. Collectively we can do much to increase these benefits.

Nursery inspection services were carried on by many states well before 1900. Plant pest regulations were needed because of outbreaks of new insects and diseases and to prevent the artificial or long distance spread of plant pests. It was recognized early that many plant pests could move on nursery plants. These regulations have provided valuable protection to the developing farm crop enterprises of the United States.

During the 1800's the U.S. had no national plant regulation. Some states had effective regulations for within state shipments. However, these regulations were not effective for interstate shipments unless the state established either border or arrival inspections. By 1900 the following pests, which continue to be serious pests in the United States, had gained entry: elm leaf beetle from

Europe in 1837; gypsy moth from France in 1869; the cotton boll weevil from Mexico in 1892; chestnut blight from Asia sometime between 1897–1899, and white pine blister rust from Europe in 1898.

Our first national plant pest legislation was the Insect Pest Act of 1905. It prohibited importation or interstate movement by any means of transportation "of any living insect notoriously injurious to cultivated crops." By itself this act was not very effective. Serious plant pests still gained entry into the U.S. and became established.

Next came the Plant Quarantine Act of 1912 which gave the United States Secretary of Agriculture broad authority to prevent entry of hazardous plant pests and to prevent spread of introduced pests of limited distribution in the U.S. The act was not fully implemented until after World War I. Quarantine 37 which regulates the importation of plants, plant products, and other articles which might carry plant pests was promulgated in 1919. In the meantime oriental fruit moth had come from Japan in 1913, Japanese beetle from Japan in 1916, European corn borer from southern Europe in 1917, and pink bollworm from Mexico in 1917.

Other major plant pests which came into the United States and became established after Quarantine 37 was invoked are: Dutch elm disease, Mexican fruit fly, Mediterranean fruit fly, white fringe beetle, imported fire ant, European chafer, witch weed, golden nematode, and citrus canker.

The U.S. Department of Agriculture (U.S.D.A.) with authority from the Quarantine Act of 1912, established interior or domestic quarantines regulating the interstate trade in plants and other articles which might carry hazardous pests. As a result considerable concern developed over possible conflict between the roles of the state departments of agriculture and the U.S.D.A. This, plus the recognized need for the states to begin to work toward uniformity in state regulations, led to the formation of four regional plant boards and eventually the National Plant Board. The first regional plant board to be established was the Western Plant Board in 1919. This was followed by the Central, the Southern, the Eastern Plant Boards and in 1926, the National Plant Board.

One of the early accomplishments of the National Plant Board was to prepare a document entitled "The Principles of Plant Quarantine." It was adopted in 1930 and has stood the test of time with only one minor amendment. This is a clear cut list of those factors which must be considered if a quarantine is to be successful.

I began to attend the Regional and National Plant Board meetings in 1959. AAN Executive Vice President, Dr. Richard White, requested that I continue his close contact with state and federal plant regulatory officials. I quickly observed that the Plant

Boards are very, very important to the nursery industry. Their meetings are devoted to well planned discussions of current insect and disease problems, research, changes in state programs and revisions to state and federal quarantines. Representatives from the U.S.D.A.'s Animal and Plant Health Protection Service are always invited and do participate in the programs.

Much of the uniformity that has been achieved in state regulations and inspection procedures has to be credited to the Plant Boards. In the early 1950's, with help from AAN, the Central Plant Board produced a nursery inspector's handbook part of which, I understand, is still in use today. The Western Plant Board continues to have a standing committee on uniform regulations.

As invited guests to the Plant Board meetings, Duane Jelinek, David Hamilton or I, as the AAN representative, have always been given time on their programs to make comments on topics of our choosing. During the board meetings we have been free to offer constructive criticism. Our attendance at these meetings has also provided us an opportunity to bring together the regulatory officials from shipping and receiving states to discuss industry problems that we know to exist between those states.

AAN representatives have had a direct input in the resolutions adopted by the Plant Boards. The presence of a nursery representative at a Plant Board meeting has automatically drawn board members attention to nursery pest problems. Each of us has had the opportunity to suggest topics for resolutions. At times we have been asked to meet with their resolutions committee to assist in drafting a resolution vital to the industry. I have even been asked to draft resolutions for the consideration of their resolutions committee.

Whenever a plant pest regulation problem occurs with an interstate or international shipment of plants there are 4 key individuals who should be involved in getting that situation resolved. In interstate shipments these are the shipping nurseryman, his state regulatory official, the receiving nurseryman and his state regulatory official. In international shipments the key persons are the shipping nurseryman, a U.S. quarantine official, the receiving nurseryman, and his national quarantine official. The regulatory officials in these cases are important because they know the requirements of the other state or country and can relate these to the nurserymen. If there has been a regulatory mistake the officials are then in a better position to get it corrected.

In 1959 I found plant board members to be men whose sole responsibility was plant inspection and regulatory work. Each was reporting directly to his state secretary of agriculture. These professionals usually had the final say on plant regulatory matters in their states. Then, as now, a few of the state chief plant regulatory officials were and remain political appointees, sometimes without experience in plant regulatory work.

Since 1959 the state departments of agriculture have changed. The Nation Association of State Departments of Agriculture (NASDA) was organized in 1915. In the mid-60's after NASDA had established its national headquarters with a full time staff, it mandated that regional organizations of state departments of agriculture employees, such as the plant boards, no longer send their resolutions directly to federal agencies as USDA and EPA or Congressional Committees. Now regional plant board resolutions must first go to the National Plant Board before being forwarded to NASDA for consideration at its annual meeting before being sent on to federal agencies and Congress.

Many of the state departments of agriculture have reorganized their administrative structure so that the senior person whose sole responsibility is plant regulatory matters now reports to a divisional director instead of directly to the state secretary of agriculture.

As a result of these changes, the nursery industry has to maintain a greater circle of contacts in the state departments of agriculture and the plant boards to have effective representation.

The nursery plant inspectors today are better trained scientifically than in the past. To expand the opportunity for in-service training some have formed a nursery inspectors' society to which many of the inspectors in the Eastern and Central Plant Board regions belong. Members in the Eastern chapter meet annually in conjunction with the Eastern Board while the Central chapter meets independently. Their programs concentrate on plant and pest identification, improved inspection techniques, and recent research findings on plant pests of their region.

It is my observation that today's plant regulatory officials are more willing than their predecessors to recognize when a quarantine has outlived its usefulness. An example of outliving its usefulness is the federal cereal leaf beetle quarantine. It was cancelled because; first, the insect had spread to most of the area in the United States to which it could be expected to spread and secondly, the successful establishment of introduced parasites had greatly diminished its economic significance.

In the mid-70's pine nematode was discovered to be the causal agent for rapid deterioration and death of Japanese black pine and other pines in the U.S. Midwest. A national quarantine was discussed. Surveys quickly showed that pine nematode was already established throughout much of the United States so plans for a national quarantine were promptly dropped.

Let me now turn to some of the observations and findings of the "Blue Ribbon Panel" appointed by the U.S. Department of Agriculture in late 1984 after citrus canker was discovered in Florida. At United Nations headquarters in Rome the subcommittee I was on was informed that the need for nursery plant regulations is universally recommended. All countries with a plant regulatory system have a regulation dealing with soil on plant roots. These vary from total prohibition of any soil to permitting soil if upon examination no hazardous pest is found in the soil ball. Similar information was given us when we visited officials of the plant protection section of the European Common Market organization.

Any of you who have traveled in Europe have undoubtedly been told that the United States quarantine 37 is unduly rigid. The panel found that some countries have regulations just as rigid and a few have regulations more strict than ours. I believe that many of the Europeans who are critical of our Quarantine 37 are not aware of the diversity of soil, climate, and crops in the United States and the overall importance of agricultural production to our economy. Another possible reason for their criticism is that we had no national quarantine regulating the importation of plants until Quarantine 37 was invoked in 1919. Our going from "no regulation" to "a firm regulation" continues to be interpreted by many Europeans as an industry instigated barrier to trade. The panel concluded that the severity of the restrictions in Quarantine 37 are directly proportional to the pest risk involved with the importation of specific plants and related articles.

Some of us on the Panel were surprised to learn that scientists are frequent violators of U.S. regulations by smuggling live plant and animal pests into the U.S. for their research. The regulations provide scientists a permit system which requires safeguards to prevent a repeat of our experience with gypsy moth. I fail to understand why a scientist who should understand the threat that exotic pests may pose to the economy of the U.S., ignores the regulations.

The U.S. Postal Service has continued to refuse to allow USDA quarantine inspectors to open and examine first class parcels suspected of containing contraband plant and animal products. The Panel after review of the situation recommended that the USDA seek legislative authority to open and inspect such parcels.

I believe that the U.S. nursery industry needs a better understanding of our state and federal quarantine systems. Each nurseryman needs to recognize that even though a pest is well established in his area and is not a problem for him it might be a serious threat under different conditions elsewhere.

Within the United States every state nursery association should urge and possibly mandate that their chief state plant regulatory official attend and take part annually in the regional plant board meeting of that region. Also that officials should attend and take part in the National Plant Board meeting at least every other year. How else can he get to know his counterparts in other states and be prepared to fully interpret the regulations of other states to the nursery industry in his state. By attending those meetings and participating he in turn is able to inform his peers of his state's regulations.

If for any reason a nurseryman feels that the nursery inspection and certification that is being provided by his state is not adequate he should go to his state nursery association seeking its assistance in getting the situation remedied. When a nurseryman has questions regarding certification of plants for foreign shipment he should contact AAN or USDA's Animal and Plant Health Inspection Service.

Today's nursery industry is in an age of specialization and very few nurseries produce a complete line of nursery stock. Every nurseryman is to some extent dependent upon another. Each one needs to cooperate and think of himself as a team member. Each nurseryman needs to respect the certification requirements of both his and other states and in turn expect nurserymen in other states to respect the requirements of his. With the increasing restrictions on pesticide usage this industry must as never before make sure that the plants we ship meet the level of freedom from insects and diseases indicated by the accompanying inspection certification.

If you live up to the certification accompanying your plants and earnestly seek the assistance of the state and federal plant inspection people to help you in making sure that you meet the certification you will find that the plant inspection regulations and quarantines in the United States are truly a "boon" and not a "bane."

COLD HARDINESS OF HERBACEOUS PERENNIALS

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Abstract. Cold hardiness was determined for certain herbaceous perennials following exposure to controlled freezing temperatures. Plants of *Lythrum*, *Achillea*, and *Gaillardia* were saleable to an exposure of −11.0°C (12°F), *Campanula* and *Coreopsis* to −9.3°C (15°F) and −7.7°C (18°F), respectively, *Chrysanthemum* and *Erysimum* to −6.0°C (21°F), *Digitalis* and *Geum* to −4.4°C (24°F), and *Kniphofia* to −2.7°C (27°F). None of the species were saleable after exposure to −12.6°C (9°F), and none of the species survived exposure to −14.3°C (6°F).

REVIEW OF LITERATURE

There has been a substantial increase in the popularity of herbaceous perennials in the past several years. In an attempt to keep pace with the increasing demand for perennials, many growers are utilizing container production. Growers are striving to produce a container perennial that will bloom and give a good display in the garden the first year it is purchased. To do this vernalization requirements are being met by overwintering container plants. However, overwintering losses can be a significant problem in container production.

Container grown plants are more susceptible to freeze damage than those grown in the ground. Roots of container plants can be exposed to temperatures of −15°C (5°F) at the same time that the roots of field-grown plants (3 in. below the surface) are only exposed to −6°C (21°F) (8).

Research in overwintering container-grown perennials has not kept pace with the needs of the perennial plant industry. Grower Richard Simon of Bluemount Nurseries stated his concern, "I hope that somewhere along the line some of the research stations would do something about determining what the root killing temperature is on some of these perennials. I think it would be helpful to the industry" (7). To this date there has been no published research on root and crown hardiness of herbaceous perennials.

The amount of winter protection required depends on the root killing temperature for the species being grown and the climate of the specific production area. By combining the knowledge of root hardiness with the amount of protection afforded by various overwintering systems, growers across the nation could minimize winter losses. The purpose of this study was to determine the cold hardiness of ten selected herbaceous perennials subjected to controlled freezing temperatures.

MATERIALS AND METHODS

Ten species were selected for the controlled freezing study based on grower suggestions concerning hardiness levels and public popularity. These species were:

Hardy *Achillea filipendulina* 'Parker's Variety', *Lythrum salicaria* 'Robert', and *Campanula glomerata* var. *acaulis.*

Marginal *Digitalis* × *mertonensis, Coreopsis grandiflora* 'Sunray', and *Gaillardia* × *grandiflora* 'Monarch Strain.'

Tender *Erysimum hieraciifolium, Kniphofia uvaria,* Pfitzer's hybrids, *Chrysanthemum coccineum,* and *Geum quellyon* 'Mrs. Bradshaw'.

The ratings of hardy, marginal, and tender were those of growers who had experienced some problems with overwintering perennials. Tender species usually exhibited winter storage losses; marginal species showed losses in some years but not in others; and hardy species usually were reliably winter-hardy and rarely showed overwintering losses. These rather arbitrary classifications were used due to the lack of published research on actual hardiness levels.

One-inch plugs were transplanted on September 18, 1986, into 1-qt containers containing a soilless mix composed of equal parts river sand, sphagnum peat moss, and styrene beads. Plants were grown outside until December 12 at which time they were moved to a cooler in which the temperature was maintained at −1°C ±1°C (30.2°F) until the freezing tests were performed starting January 11, 1987.

A total of 12 plants of each species were subjected to each test temperature. Test temperatures [in Centigrade followed by Fahrenheit] were as follows:

−1.1 (30), −2.7 (27), −4.4 (24), −6.0 (21), −7.7 (18), −9.3 (15), −11 (12), −12.6 (9), and −14.3 (6).

There were three replications of each species within each of the nine temperature treatments repeated over four blocks (weeks) of time.

Thirty plants (3/species) were placed pot to pot into a low temperature freezer cabinet in a completely random design. A 15 cm (6 in.) long ungrounded copper-constantan thermocouple probe was placed approximately 5 cm into the medium in the center of 6 different containers. Temperatures were recorded every 5 minutes.

Temperatures were lowered from −1.1°C (30°F) at the rate of 2.7°C (5°F) per hour until the treatment level was reached. Once the medium in the containers reached the test temperature, plants were held at the temperature for a least 1 hour. Plants were removed from the freezer and placed in a cooler at 2°C (36°F) to thaw gradually. After thawing plants were placed in a greenhouse (20.9°C (70°F)) for forcing.

A qualitative analysis was done by a panel of 4 judges to rate saleable quality on a scale of 1 to 5, with 1 being dead, 2-alive but saleable, 3 to 5 saleable with 5 of highest quality. Analysis of covariance and simple linear regression techniques were performed. Analysis of covariance was performed with time at four levels and temperature as the covariate to predict regrowth.

RESULTS AND DISCUSSION

There was a great variation in the hardiness levels among the different species. Test temperatures that produced saleable plants ranged from −11°C (12°F) for the hardy species to −2.7°C (27°F) for the most tender species (Table 1). None of the species were saleable after an exposure to −12.6°C (9°F), and none of the species survived exposure to −14.3°C (6°F).

Table 1. Cold hardiness ratings of ten herbaceous perennials following controlled freezing tests.

Species	Temperature °C	°F
Hardy		
Achillea filipendulina 'Parker's Variety'	−11.0	12[z]
Gaillardia × *grandiflora* 'Monarch Strain'	−11.0	12
Lythrum salicaria 'Robert'	−11.0	12
Intermediate		
Campanula glomerata var. *acaulis*	−9.3	15
Coreopsis grandiflora 'Sunray'	−7.7	18
Tender		
Chrysanthemum coccineum	−6.0	21
Digitalis × *mertonensis*	−4.4	24
Erysimum hieraciifolium	−6.0	21
Geum quellyon 'Mrs Bradshaw'	−4.4	24
Kniphofia uvaria, Pfitzer's hybrids	−2.7	27

[z] Temperature exposure in Centigrade and Fahrenheit that resulted in saleable plants (at least a rating of 3 on a scale of 1 to 5 with 5 being best)

Of the ten species evaluated *Lythrum*, *Achillea*, and *Gaillardia* survived the lowest temperatures. Regression analysis of the regrowth ratings reveals that saleable plants of these three species could result if the plants were exposed to −11°C (12°F) or slightly lower. An example of the regression curves for these 3 species is shown for *Achillea* in Figure 1. The findings that *Lythrum* and *Achillea* are hardy species producing saleable plants after an exposure to −11°C (12°F) was not unexpected. Growers have reported both of these plants as being cold hardy in their overwintering systems (1, 5).

Gaillardia has been reported as being hardy in areas with minimum low temperatures of −30 to −20°F; however, growers

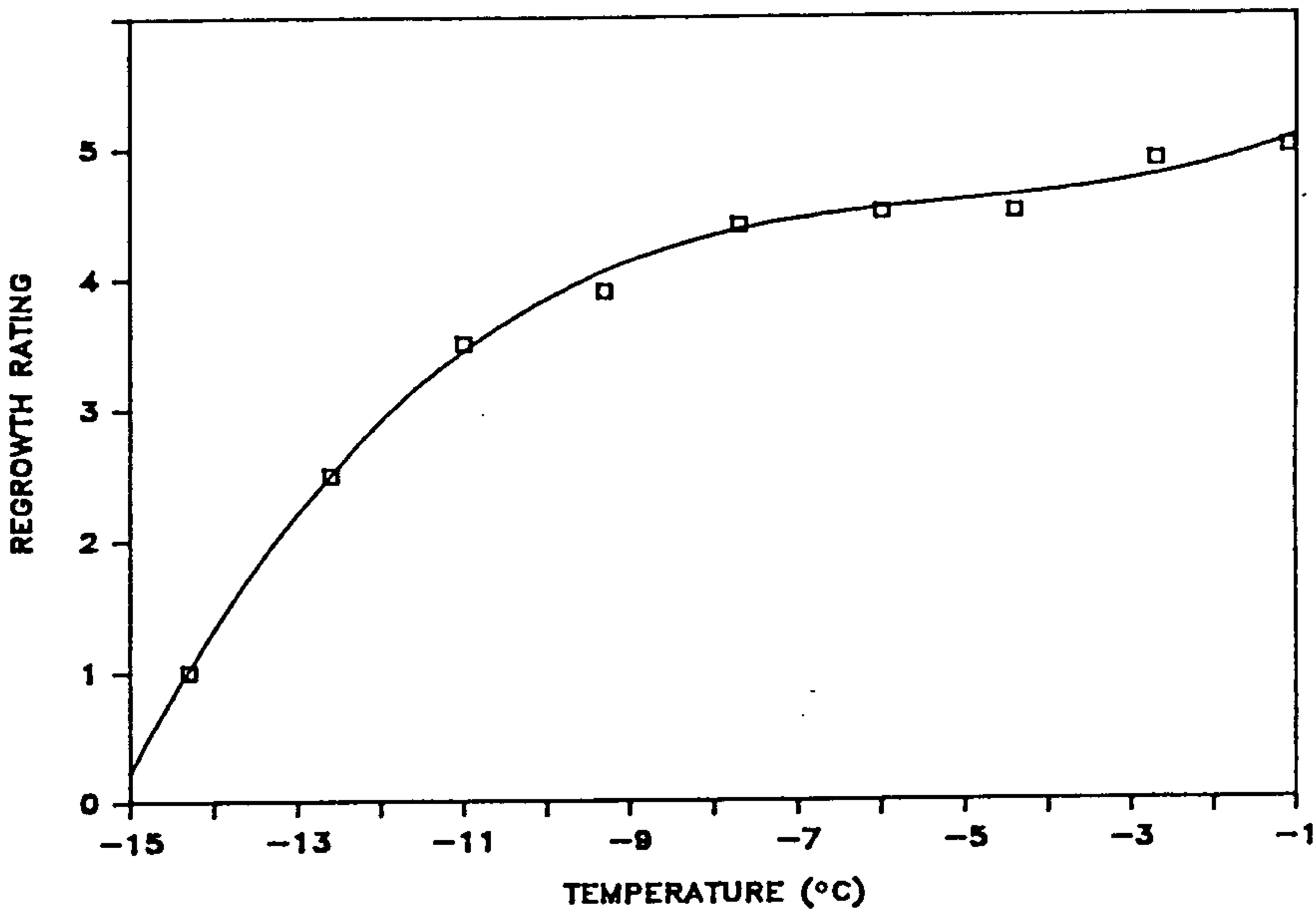

Figure 1. Influence of varying low temperature exposure on regrowth quality of *Achillea filipendulina* 'Parker's Variety.' r = .78 y=5.38768272 + (.35534847) deg + (.05876237) deg*deg + (.00386450) deg*deg*deg*.

have experienced trouble overwintering this species. DiSabato-Aust (2) reported that *Gaillardia* was damaged when stored under thermal blanket in 1985–86 even though container soil temperature never dropped below −4.9°C (23°F) which was well above the temperature in the freezing chamber. *Gaillardia* requires good drainage and wet overwintering conditions can be fatal (9). Physical storage conditions may be the reason for poor overwintering and not because of a lack of cold hardiness.

Species surviving intermediate temperatures included *Campanula* and *Coreopsis* with saleable plants occurring at −9.3°C (15°F) and −7.7°C (18°F), respectively. The regression slope for *Campanula* is indicated in Figure 2. Note that the peak of the slope moves further to the right as the hardiness of the perennials become lower.

Campanula is viewed as being hardy by the growers but *Coreopsis* has exhibited variable responses. Other research has also shown *Coreopsis* to be a variable performer. Heiden (3) tested bareroot *Coreopsis* plants at different shipping temperatures, different holding temperatures, and various holding periods. He found that this species exhibited various regrowth responses which did not show any definite trends due in part to erratic plant survival rates. Growers report losses during warm winters and variablility in survival due to the size of plants placed in storage.

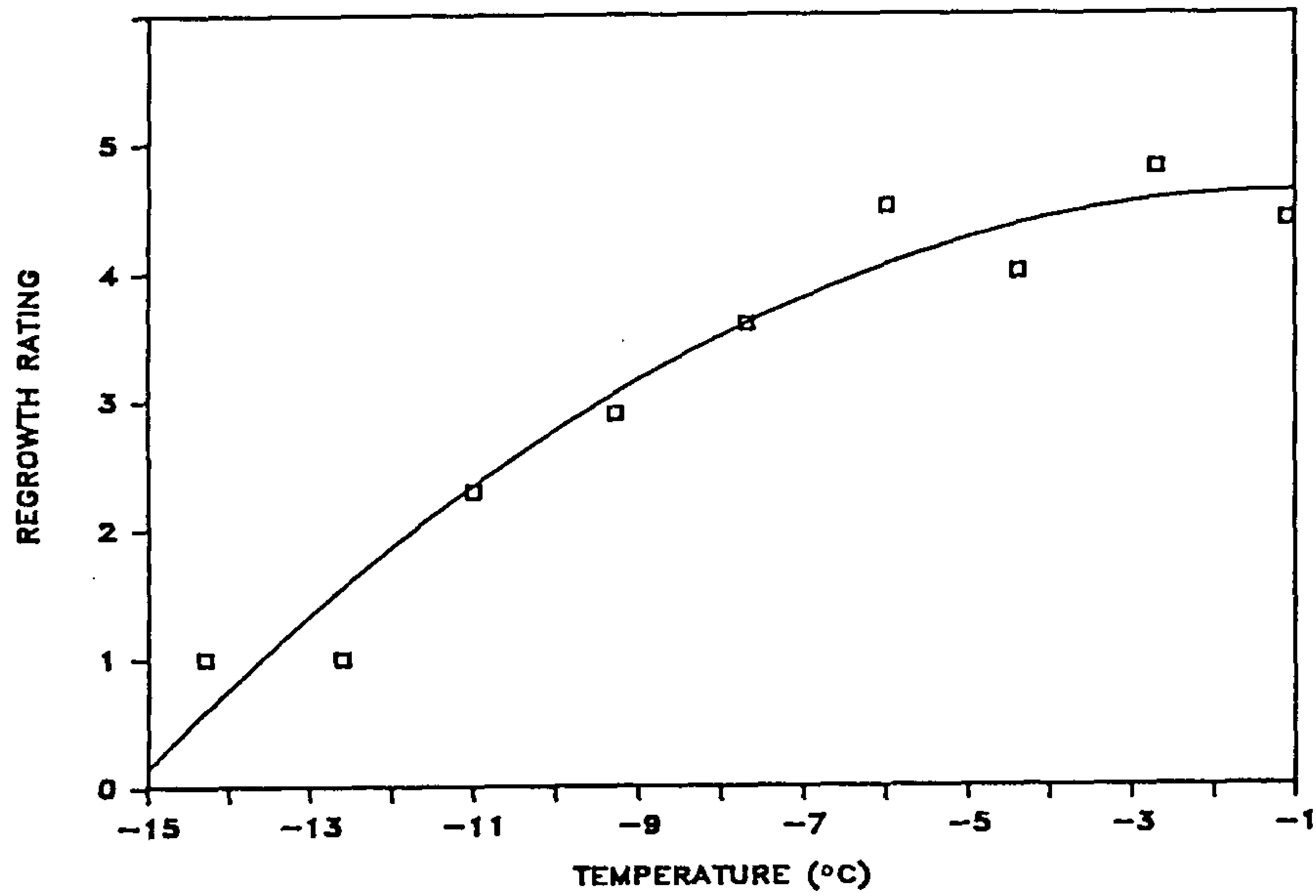

Figure 2. Influence of varying low temperature exposure on regrowth quality of *Campanula glomerata* var. *acaulis*. r = .67 y=4.58964257 + (.05028991) deg + (-.02310418) deg*deg.

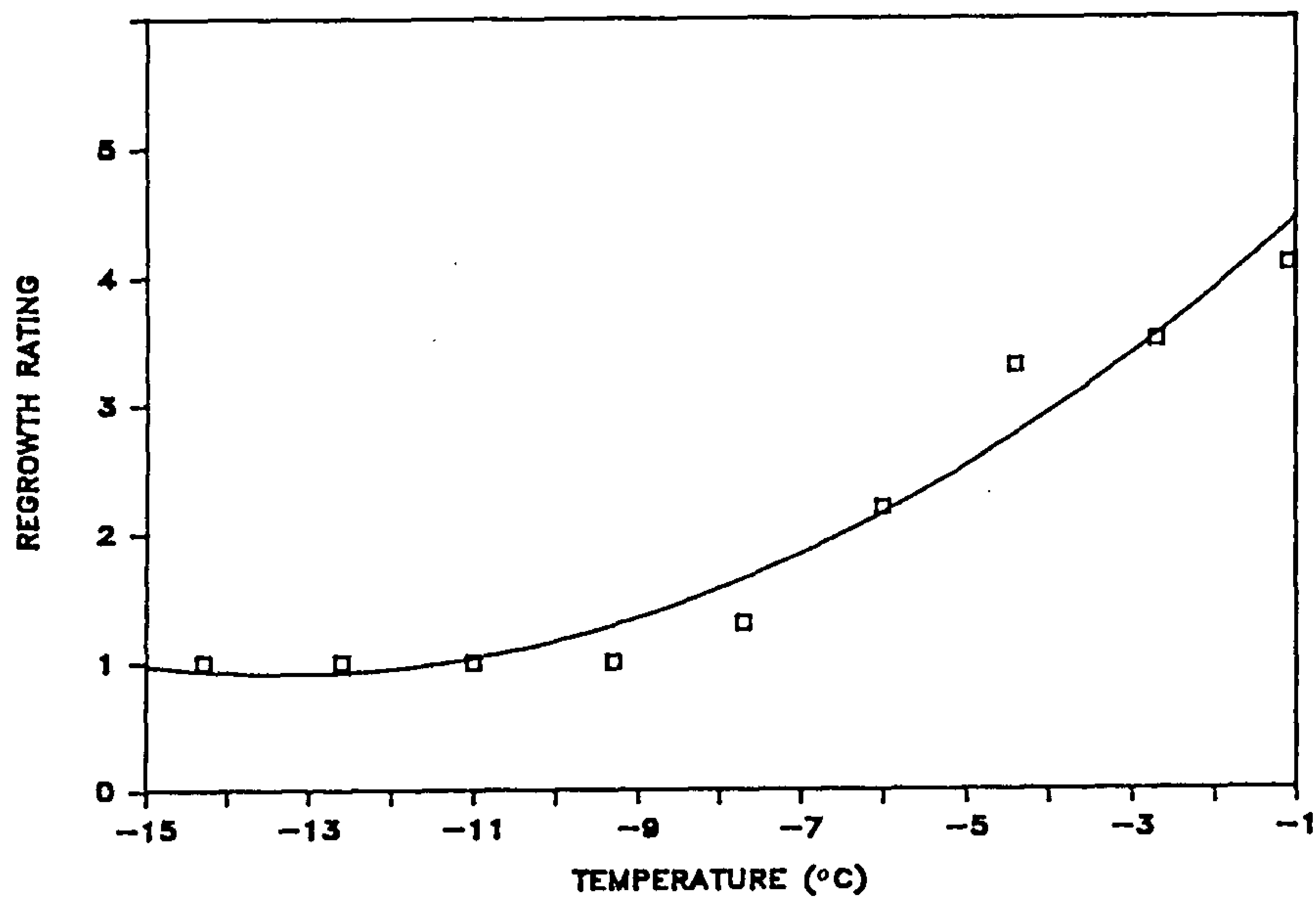

Figure 3. Influence of varying low temperature exposure on regrowth quality of *Digitalis* × *mertonensis*. r = .64 y=5.03973141 + (.61946936) deg + (.02322330) deg*deg.

There were 5 species that we considered tender due to performance after exposure to −6.0°C (21°F) or less. *Digitalis* and *Geum* are examples of plants in the mid-range of this hardiness zone with saleable plants found at −4.4°C (24°F). The regression for *Digitalis* is indicated in Figure 3.

According to DiSabato-Aust plants of *Digitalis* were not rated saleable after overwintering in a single layer poly house in 1985–86 (2). The minimum soil temperature recorded was −7.1°C (19°F). *Digitalis* is considered marginal by growers (10). It is subject to root and stem rot and growers try to avoid placing thermal blankets directly on the plants to avoid loss from these diseases.

Magbool (4) reported that bareroot plants of Geum did not have any observable growth after being stored for 6 months at −5 °C (23°F) or −10°C (14°F). DiSabato-Aust (2) reported *Geum* as unsaleable after storage in various overwintering structures where container soil temperatures were −7.1°C (19°F), −1.6°C (29°F) or −4.9°C (23°F). *Geum* is usually overwintered in a minimum heat greenhouse and moved to cold frames in the spring (1.5). It is not reliably hardy in northern areas and wet conditions can be fatal (9).

Kniphofia proved to be the most tender species studied with a saleable plant at −2.7°C (27°F). The regression curve for this species is shown in Figure 4. Growers consider it a tender species and often overwinter it in cool greenhouses (5). It is considered a tender plant

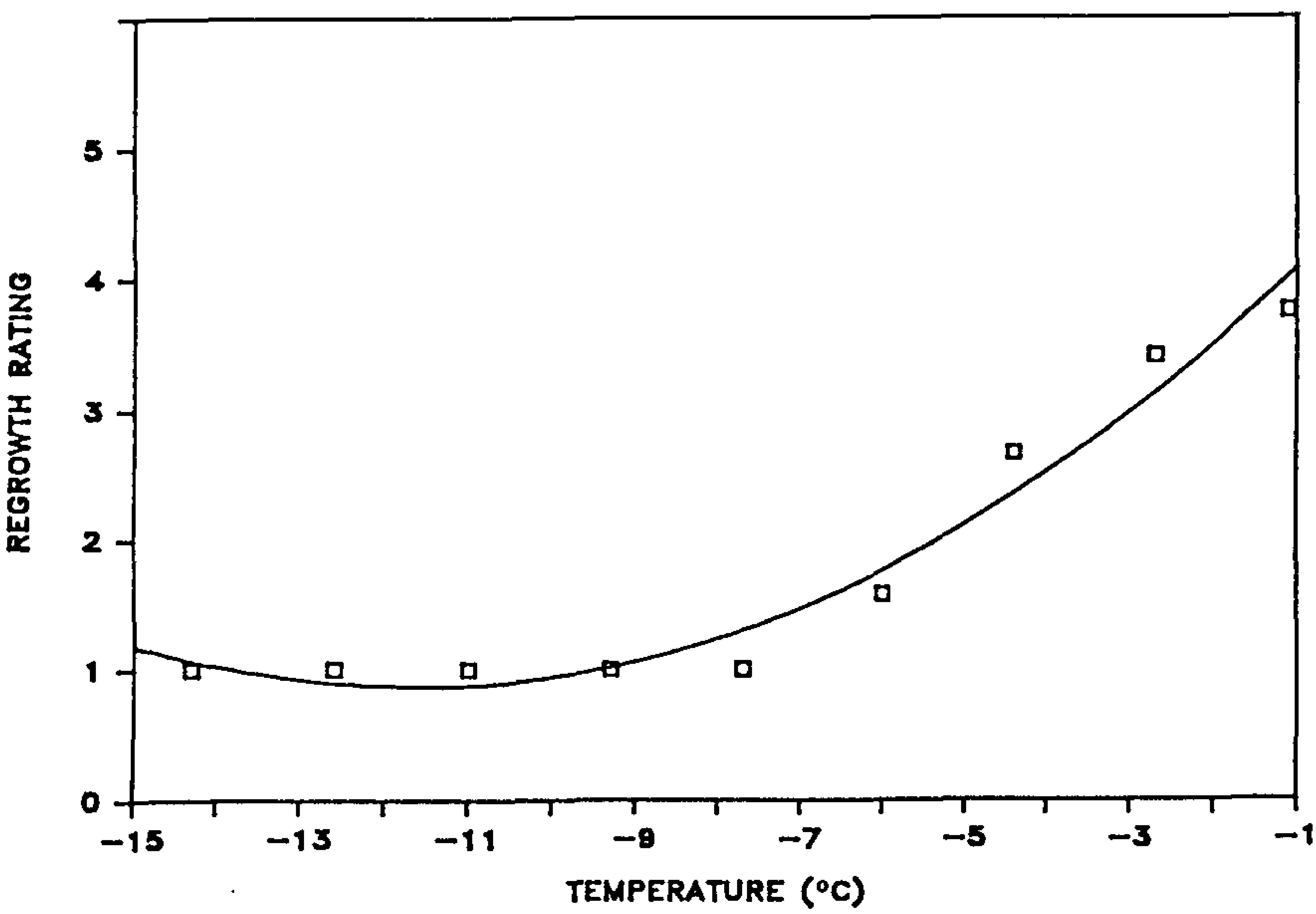

Figure 4. Influence of varying low temperature exposure on regrowth of *Kniphofia uvaria*, Pfitzer's hybrids. r = .66 y=4.696886424 + (.65743339) deg + (.02820841) deg*deg.

for northern gardens and requires mulching to overwinter when grown in the soil.

These results are only from a one-year study. Future work will be continued to survey additional species. An area of additional study might include determination of hardiness cycles. Shimizu (6) reported maximum hardiness of *Narcissus* 'White Cheerfulness' roots was reached in December followed by January and February. Roots were least hardy in March. This may be an important factor in determining the true hardiness levels of herbaceous plants. These levels could then be related to overwintering losses in the field, i.e., are losses greater if there is a period of subfreezing temperature in December or if these temperatures occur in February?

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BILL FLEMER: What type of bait are you putting under the thermal blankets?

ELTON SMITH: We are using a bait block, Eaton Bait block, that is apple scented, and available from a firm in Cleveland, Ohio. An important key is first controlling the mice outside the perimeter early in October; then bait inside the houses. This keeps them from coming into the houses.

Thursday Morning, December 10, 1987

The morning session was convened at 8:00 a.m. with Charles Hildebrant serving as moderator.

PLANT PRODUCTION WITH FOG

CHRISTOPHER S. ROGERS

Weston Nurseries, Inc.
Hopkinton, Massachusetts 01748

Weston Nurseries, Inc. chose to invest in a fog-producing machine for two reasons. First, the lack of labor that we could foresee in our area, and second, the increased greenhouse space being used due to our expanding tissue culture lab.

By using fog in conjunction with direct-sticking of softwood cuttings into flats, production time has decreased, two greenhouses that were vacant all summer long are now being used for propagation, and rooting plants with which I had difficulty are much easier to propagate.

After a couple of years of experimenting with fog propagation, I am currently using fog in three ways. First, fog is used for propagating easy to root plants to decrease production time. Second, it is used for rooting plants that do not overwinter very well if their root systems are disturbed after rooting. Thirdly, fog is used for experimenting with plants that I have had little or no success with by other means.

Four different media types have been tried at Weston Nurseries.

1) Washed concrete sand and coarse perlite (9:1, v/v). This medium is heavy and workers dislike moving the flats. One has to water this medium often during the summer. Cuttings, however, root quickly with high percentages. The water holding capacity is very low. After rooting has occurred, constant attention must be given to the plants because the medium quickly dries out.

2) Composted Southern pine bark, washed concrete sand, and coarse perlite (3:2:1, v/v/v). This medium is heavy and workers dislike moving the flats. Rooting percentages, however, are high. It is easy to overwinter the rooted cuttings. In the spring the medium has to be watered daily.

3) Peat moss and coarse perlite (1:1, v/v). This medium is easy to handle, and light weight. Cuttings root and overwinter well. Cuttings of some cultivars decay in it, however.

4) Peat moss and coarse perlite, and composted Southern pine bark. This medium is easy to handle, and light weight. Plants overwinter well in it. Decay of cuttings has not been a problem.

Three of these media are currently being used. The washed concrete sand and coarse perlite medium is used on *Syringa vulgaris* cultivars, *Metasequoia glyptostroboides, Cornus florida* 'Rubra,' *Hamamelis mollis,* 'Brevipetala' and *Stewartia pseudocamellia.* Deciduous azaleas root well in the peat moss, coarse perlite, composted Southern pine bark medium. For the remainder of our cuttings the peat moss and coarse perlite medium is used.

The containers for rooting vary with the type of plants being propagated. The container used most is the shallow galvanized Norman flats. They seem to be very durable, the easiest to clean, and take up a relatively small space when not being used.

Rooting hormones are either Dip 'N Gro 1:10 or an 0.8% IBA talc formulation.

The rooting structure is quite simple. It is an inflated hoop tent with two layers of clear polyethylene. For shade 63% Armex black polypropylene shade cloth is placed over the plastic on the outsides of the greenhouses. The rooting containers are placed on the floor or

Table 1. Rooting percentages of bench propagated vs. fog direct-stick cuttings.

Plant	5 yr avg Bench propagated	2 yr avg Fog direct-stick
Berberis thunbergi cultivars*	90%	0%
Buddleia davidii cultivars	99	100
Cornus florida 'Rubra'*	70	98
C. stolonifera, 'Flaviramea'	99	100
Calluna vulgaris 'Crispa'*	80	100
Chaenomeles speciosa cultivars	95	100
Deutzia cultivars	99	100
Hamamelis mollis 'Brevipetala'	80	98
Hibiscus syriacus cultivars	100	100
Hydrangea cultivars	90	98
evergreen azaleas*	90	95
Kalmia angustifolia 'Alba'*	20	98
*Metasequoia glyptostroboides**	30	95
Parthenocissus cultivars*	99	100
Rhododendron 'Lemon Drop'	95	99
R. 'Pink & Sweet'	90	100
*Stewartia pseudocamellia**	75	95
Spiraea × *bumalda* 'Anthony Waterer'	100	100
Symphoricarpos cultivars	100	100
*Syringa potaninii**	40	75
Syringa vulgaris 'Ludwig Spaeth'	66	72
Vaccinium corymbosum cultivars	75	0
Viburnum plicatum f. *tomentosum* cultivars	90	99

*Rooted in the 90 to 95°F greenhouse

on wood benches. Decay is not a problem and no fungicides are needed. The cuttings are either healthy and green, and root; or turn brown after 2 to 3 days and decay.

The environment in which the cuttings are rooted varies in the two greenhouses. One greenhouse has a 16 ft tall ceiling and the fog nozzles are mounted 10 ft above the floor. The air temperature above the rooting cuttings rarely gets above 80°F during summer days. The other greenhouse is a conventional 22 × 96 ft hoop house. The fog nozzles are one foot from the flats and the air temperature stays between 90 and 95°F on sunny summer days. The cooler greenhouse is filled first and then cuttings are placed in the hotter greenhouse. Both houses remain at or above 90% humidity during the rooting period. No additional heat is used in either greenhouse.

The rooted cuttings are hardened off when the root ball is about ¾ in. (2 cm.) in diameter. Gradually, the humidity is lowered in the greenhouses until the plants do not need fog to survive. The cuttings from the 16 ft tall greenhouse, once hardened, must be moved to

Table 2. Conventional bench-propagated vs direct-stick fog for evergreen azaleas (cost/unit at $10.00/hr*).

Step	Man-Hours	Cost
BENCH PROPAGATED		
Field Cuttings	16.25	162.50
Media/bench preparation	40.00	400.00
Sticking	39.00	390.00
Flatting	58.50	585.00
Flats moved to winter storage	7.00	70.00
Mist setting/observation	3.00	30.00
Pesticide application	0.5	5.00
Materials:		
14 bags peat moss		80.50
14 bags coarse perlite		102.90
2 gal. Clorox bleach		2.00
1 lb benomyl		18.00
	Total	$1845.90
	$1845.90/17044 cuttings =	10.8¢/cutting
FOG DIRECT-STICK		
Field cuttings	16.25	162.50
Media preparation	17.00	170.00
Sticking	39.00	390.00
Maintenance of nozzles/observation	2.80	28.00
Materials:		
14 bags peat moss		80.50
14 bags perlite		102.90
10 Lb Aqua-Gro		22.00
2 gal. Clorox bleach		2.00
	Total	$957.90
	$957.90/17044 cuttings =	5.6¢/cutting

*Average total labor cost to the nursery in propagation other winter holding houses. This greenhouse must be empty for different uses throughout the winter. In the 22 × 96 ft. greenhouse the rooted cuttings remain at 40 to 45°F until spring when they are either planted in raised beds or containerized.

Although there is little increase in rooting percentages among the many plants tried (Table 1), significant savings are possible with this method (Table 2), because production steps are reduced by direct sticking cuttings (Table 3). At Weston Nurseries man-hours are reduced by 48% when fog is combined with direct sticking of cuttings (Table 3).

Table 3. Cutting production steps at Weston Nurseries, Inc. for conventional bench propagated vs direct-stick fog methods.

Bench propagated	Fog direct-stick
1. Remove used media from benches	1. Clorox 1:9 flats
2. Repair benches	2. Mix media
3. Clorox 1:9 entire greenhouse	3. Fill flats
4. Fill empty benches with media	4. Move flats to fog greenhouse
5. Mix media in benches	5. Stick cuttings
6. Stick cuttings	6. Maintain cuttings
7. Maintain cuttings	
8. Flat rooted cuttings	
9. Move flatted rooted cuttings to harden off	
10. Move rooted cuttings to winter storage	

BRIAN DECKER: What about clogging and algae?

CHRIS ROGERS: We rarely have a problem with either one. The nozzles are checked on a daily basis. If one is clogged I remove it and replace it with an extra. I clean my nozzles with Clorox/H_2O (1:10 v/v) for 1 hour.

BRUCE BRIGGS: How do you keep the temperature from building up on very hot days?

CHRIS ROGERS: In our tall greenhouse the temperature is never above 80°F and the fans do not run. In the 22 × 96 ft greenhouse we just use the Acme fans that are in the greenhouse. I run the temperature a little higher (90 to 95°F) with the lower houses.

MIST BOOMS FOR PROPAGATING PLANTS

DALE DEPPE

Spring Meadow Nursery
Grand Haven, Michigan 49417

All of us are interested in mist systems. As propagators, we have learned that misting is one of the most critical elements in the rooting of cuttings. Our intense love-hate relationship with the mist nozzle has caused a few gray hairs in many of us. Also, I think more cuttings have died because of over or under misting than any other reasons. If you have ever been involved in the design of a mist system or have learned to live with someone else's mistakes, you'll like the mist boom concept.

A mist boom, as we call it at Spring Meadow Nursery, is actually a traveling irrigator. Traveling irrigators were developed to water seeded plug trays in the bedding plant industry. A long greenhouse can be watered or misted so that each plug cell or cutting receives the same amount of water because the spray pattern is exactly the same all along the width of a boom. Uniformity is the key in producing quality bedding plants and also for us in using a mist system.

A mist boom is identical to the spray boom on the back of a field sprayer, except the mist boom travels down the length of the greenhouse riding on a set of rails or tracks. It pulls a hose for water and an electric cord for power. By adjusting the travel speed and using different sized nozzles, the spray volume can be changed to meet the needs of any propagator.

Let's talk about mist nozzles for a moment. What is it that you presently use? Is is Flora-Mist foggers, Spray Stakes, Perfect nozzles, Eddy Mist nozzles, or the Spraying System's ¼E10? Whichever brand you use, try and explain to someone how a nozzle that sprays in a circle can be used to mist a square propagation bed. When we design a system with circle pattern misters, we design for overlap in the spray so that every cutting is misted. Actually, most of our cuttings receive anywhere from two to four times the required mist in order to ensure that all of the cuttings get some mist. We have all had problems with mist coverage which are usually solved by adding more nozzles or by running the mist system longer than needed. After the cuttings decay, we start to lighten up our media and improve our drainage in order to match the water usage.

A traveling mist boom has a flat fan nozzle. This nozzle has a pattern that is 28 in. wide at a 20 in. height above the cuttings. With nozzles 14 in. apart, the mist pattern is 100% overlap. Every square inch of propagation bed receives the same water volume. Every cutting receives the same mist. Every cell in a plug tray produces a uniform rooted cuttings.

But, what about water usage? As your propagation area increases and you add more mist nozzles, all too soon the water pump is inadequate, and the water tank is under sized. As you add zones, you have to be sure the zones cycle after each other because if more than two or three come on at the same time, the water pressure falls to the point where mist coverage is reduced. At Spring Meadow Nursery, 6000 sq ft of propagation area required 64 gallons of water in one mist cycle. Now with the traveling boom, 10,000 square feet of propagation area only requires 8 gallons of water in one mist cycle. In addition, the mist boom sprays continuously for two minutes to complete one cycle.

Controls for misting cycles are the standard time clock type. A 24 hour clock is used to turn the system on and off. A one-hour clock is used for starting the mist cycle. If you prefer, there is a photo cell available that will adjust mist cycles based on light intensity.

A traveling mist boom can be installed by you in almost any type of greenhouse. Economics would dictate that if the greenhouse is wider and longer, the cost per square foot would be reduced. At Spring Meadow Nursery, our total system cost is approximately $0.60/sq ft. At some other nurseries, that cost is well below $0.40/sq ft. Compared to the cost of mist nozzles, time clocks, solenoid valves, and line strainers in our old system, the traveling mist boom is more cost effective.

A traveling mist boom moves from one end of the greenhouse to the other end on a pipe rail or track. The pipe rails are suspended from the top of the greenhouse. The mist boom moves along the pipe rails on rubber wheels above the propagation area. The speed of travel is changed by moving the drive belt from one pulley to another or with variable speed motors.

The water supply for our traveling booms is connected at the center of the greenhouse. A hose cage holds the hose and allows it to move back and forth with the boom. When the boom is at either end of the greenhouse, the hose is extended to its full length. As the boom returns down the greenhouse, a hose cage system keeps the hose up and out of the way. Advantages of locating the hose in the center include reducing the length of hose required by one-half, and less loss of water pressure. An alternate method is for the water supply to be connected at one end of the greenhouse. In this case, the hose length is equal to the greenhouse length. The hose is looped many times and hangs from rollers attached to the pipe rail. As the boom travels, the hose becomes fully extended. As the boom returns, the hose will bunch up and be stored at one end of the greenhouse. This method is cheaper than a hose cage and is very effective until the length of the greenhouse exceeds 200 ft.

At Spring Meadow Nursery, our misting area consists of two gutter-connect greenhouses; each 35 × 144 ft. Each greenhouse has a Growing Systems mist boom. In one house, we utilize the floor space as misting area. In the other house, we have installed rolling benches and bottom heat. When laying out the misting area, the beds or benches should be perpendicular to the boom's travel. As the boom moves down the greenhouse, different beds or benches can be watered or not watered as needed. By installing the proper switching, it is possible to water one bed every 4 minutes while watering another bed every 6 minutes.

New applications for the traveling irrigator system continue to be developed. A small injector is now available. This injector rides along with the boom and is capable of applying fertilizer or pesticide. Toxic chemicals can be applied to the crop without personnel being present. High pressure fog traveling along with the boom promises to outperform even the best designed stationary system available today.

When planning changes to your present mist system or when making expansion plans, consider the advantages of a traveling boom mist system.

PROPAGATION OF ALPINES AND THEIR PRACTICAL USES

PRISCILLA GALPIN TWOMBLY

Oliver Nurseries
Fairfield, Connecticut 06430

Oliver Nurseries is a small retail nursery in Connecticut specializing in dwarf and rare plants, including dwarf conifers, azaleas and rhododendrons, alpines, and rock garden plants. Most of the alpines are propagated and grown on at the nursery. This paper will deal with what constitutes an alpine plant, their propagation, and where they can be used in the home landscape.

In the strictest sense, alpines are considered to be plants that grow above the timberline. They may be evergreen or deciduous shrubs, or they may be herbaceous perennials, but they are never annuals as the growing season is too short to manage a full life cycle in one season.

Alpines are characterized most often by foliage pressed very close to the ground, which is a result of the severe climate in the high mountains. In addition, their flowers are quite large in proportion to their foliage. In part this is because their foliage grows so slowly and is so tightly compressed that their flowers seem overly large against it. Occasionally, when an alpine plant is taken out of that severe climate and grown in a more temperate climate, the foliage expands and loosens up, and the flowers appear to be more in proportion space as misting area. In the other house, we have installed rolling benches and bottom heat. When laying out the misting area, the beds or benches should be perpendicular to the boom's travel. As the boom moves down the greenhouse, different beds or benches can be watered or not watered as needed. By installing the proper switching, it is possible to water one bed every 4 minutes while watering another bed every 6 minutes.

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In the looser sense of the word, and the more commonly accepted use, "alpines" encompasses a much wider group of plants than those that grow above timberline. Usually it refers to any plant that is suitable for a rock garden and can include any dwarf shrub, perennial, or biennial that looks appropriate. But in this paper, the propagation of alpines will mostly be concerned with the more difficult plants and the challenges of growing high-mountain plants.

There are several mountain ranges in the United States which are high enough to have alpine plants. In the east we are essentially limited to the White Mountains, where there are some very fine alpine plants but not a great deal of diversity. In the west, the greatest mountain range is the Rockies, which stretches from northern New Mexico all the way to northern Canada and includes many types of excellent alpine plants, some of which are relatively easy to grow but many of which are very difficult. Examples include *Dryas octopetala* (not particularly difficult to grow, but a little tricky to get started), *Eritrichium nanum,* and one of the cushion phloxes. *Diapensiă lapponica,* an endemic of the Presidential range of the White Mountains in New Hampshire, is an example of one of the more difficult Eastern alpines.

Here in the East, we are fortunate to have an abundant supply of stone, a prerequisite to growing alpines. But not all of us have natural rock outcroppings on our properties, nor do we all have sloping areas, ideal for rock gardens because of the improved drainage inherent in a slope, so we must create natural looking situations for the plants. A flat area does not preclude the possibility of a rock garden, as flat areas occur frequently in the mountains and are called either an alpine lawn, where plants all grow together, or a rocky pasture, where alpine plants grow in combination with the stones which litter the ground. If there is a slope, it can either be planted as a rock garden, or a retaining wall or "raised bed" preferably built of stone, can be constructed. The resulting "raised bed" can be planted as well as all the crevices in the spaces between the stones if, instead of mortar being used, soil is used as the cement. If there is no slope at all, a free-standing raised bed can be constructed, and the resulting four sides of the walls (or however many you choose to make) can be planted with alpines. This creates an ideal situation for the plants, giving them good air circulation, perfect drainage at the crown, and a cool root run in the crevices between the stones. Limestone can be used for the "lime lovers", if available, and since the walls of the raised bed face in all directions, the plants can be situated so that they receive their best light conditions: south or west facing for the "sun lovers", north or east facing for those that do best with bright but indirect light. The top of the raised bed can also be planted with "sun lovers". An advantage of planting a wall is that a wall of inferior stone can be camouflaged with vigorously growing plants, or a finely built wall of superior stone can be enhanced using the tighter, cushion-forming alpines.

An alternative to this idea of the raised bed is that of the trough or sink garden, which originated with the British when their stone watering troughs and sinks no longer served a purpose and they began planting them with dwarf plants. Ideal for this purpose are the tiny alpines, as roughly 20 to 25 of the smaller plants can be fit in a space 20 × 30 in. Realizing that stone watering troughs are a rare commodity in this country, we at Oliver Nurseries have devised a method of constructing them out of a combination of peat, sand, and cement which looks surprisingly like stone when dry. When filled with a gritty soil mixture and planted with a "landscape" of dwarf plants, the trough becomes a somewhat portable rock garden in miniature. Placed on a patio or by the front door, alone or in combination with others, troughs can be used to grow quite a number of difficult plants whose needs for special light conditions or soil can be met fairly easily with a little forethought. Some of the more difficult plants that we grow in troughs include *Dianthus alpinus, Gentiana acaulis, G. verna* [syn. *G. angulosa*], *Campanula aucheri, Primula auricula* var. *alpina* (syn. *P. alpina*), and *Penstemon.*

Most of our propagation is by seed or by cuttings. We collect seed from our own stock plants, and we belong to five alpine garden societies throughout the world which offer seed exchange programs. Seed is sown in the winter, and placed directly outside on benches protected by screening material. This protects against strong driving rains, burning sun, and curious animals. Seeds are sown in square plastic pots, usually 3½ in. square but occasionally as large as 4½ in. in Jiffy Mix plus coarse sand (1:1, v/v) with a light feeding of Osmocote 14-14-14 mixed into the medium. The seeds are sown lightly on the mix, then topdressed with a thin layer of granite grit (purchased at poultry suppliers) to protect the seeds from washing away during watering or in heavy rains. The pots are then soaked until thoroughly moistened, then placed outside on benches to freeze.

Seed germination begins in March and continues through June and sporadically thereafter. Seed pots that show no signs of germination are held for two years and then discarded. Depending on their size, seedlings are transplanted when they have either one or two sets of true leaves. The pots are allowed to dry for a few days before transplanting; this facilitates separating the seedlings, which occasionally are quite crowded. They are lined out into 14 × 16 × 2½ in. flats, 30 to a flat, in rows of 6 × 5. Occasionally, with either very tiny plants or much larger plants, seedlings are lined out closer or farther apart, respectively. We feel that lining out in flats is better than potting up each seedling individually because it facilitates keeping an even moisture level in the flat; they take up less space than they would in pots, and it is a more natural situation for the seedlings to be growing in the company of others. The soil mix used is a very well drained one, and the pH ranges between 5.8 and 6.3. The flats are top-dressed with Osmocote 14-14-14, and then with a layer of stone mulch which mostly protects the small plants from the drip of the lath. Flats are placed on the ground in a lath house, where they will stay until the following spring, when they will be potted up for sale.

When most of our seedlings have been lined out, we begin taking cuttings, usually around the end of June. Stock plants are either planted out in the gardens in the nursery, in "stock troughs", or occasionally they are kept in pots in a stock area. We use Wood's Rooting Compound at the rate of 20:1 (v/v) in most cases, 10:1 with particularly hard-to-root species. Cuttings are stuck in flats, quite close but without touching. The mix consists of super coarse perlite, coarse sand, and screened peat (8:2:1, v/v/v). Flats are placed under a mist system which is on a 6 min timer, so the mist goes off for 6 sec every 6 min. This is a fairly heavy mist, which is why the mix has to be so well drained. Propagation is done in a hoop house where it gets quite hot in the summer so the mist helps to cool the plants.

When the cuttings have rooted, usually within 3 to 4 weeks, they are moved into flats in the same manner as the seedlings, and placed in a lath house. Most will winter outdoors under the cover of a layer of microfoam and plastic, but those that are moved on late in the season, i.e. September, are wintered over in a minimum heat hoop house.

Some of the problems that we have encountered are due to the inherent nature of the alpines. Many of them, being from a high mountain, open environment, do not do well under the close, humid atmosphere of a mist system. So, the difficulty lies in getting them to root before they decay under the mist. After rooting, they are moved on immediately before they deteriorate any further. Another limitation in rooting alpines is the size of the cutting we can take. In many cases, the growth on the plants is so compressed, that the longest stem we can get may only be ¼ in. long, so contact with the cutting mix is very limited. Cuttings are easily dislodged, and many cuttings can be lost that way. But usually the percentage of those rooting is quite good when they are watched carefully.

Alpines are a beautiful and fascinating group of plants, and a continuing challenge to even the best growers. Although not the most economically lucrative plants to grow, they attract a large number of customers who then buy some of the "bread and butter" items in the nursery. Therefore I think they pay their way by drawing in customers looking for the rare and unusual.

EDITOR'S NOTE: The following four papers by Wayne Mezitt, William Flemer III, Richard Jaynes, and James Cross are all part of a panel discussion: *Maintaining Credibility in Plant Introductions.* Wayne Mezitt was moderator.

MAINTAINING CREDIBILITY IN PLANT INTRODUCTIONS I

R. WAYNE MEZITT

Weston Nurseries, Inc.
Hopkinton, Massachusetts 01748

Over the last several years the nursery industry has experienced an upsurge in the number of new cultivars becoming available. As progressive as this trend appears on the surface, the implications become far deeper as we explore the commitments that follow. This situation offers large potential rewards along with some special challenges. I believe our industry currently has a real need for self examination; we as propagators are probably in the appropriate position to begin the process.

WHY DO NEW PLANTS INTEREST US?

Many aspects of new introductions are exciting to propagators, growers and horticultural salespeople. Primary to many of us is an improvement in quality of one or more of these characteristics: cold hardiness, heat tolerance, adaptability to stressful climates, better color in flower or foliage, improved growth habit, flowering season, fragrance, seasonal appeal, and numerous other advantages. Improvements that make it easier for the ultimate customer to be successful and happy with his/her purchase of the new cultivar are also of interest.

A second area of interest includes resistance to such problems as insects and diseases; tolerance of soil compaction; wet or dry growing conditions; adaptability to sun or shade, wind, short seasons, etc.

A third area appeals especially to the grower. Qualities, such as ease of propagation; ability to produce a saleable plant that looks good to the customer; and the ability of a new cultivar to "make up", dig and ship successfully are all vitally important in creating a large market for it.

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A fourth area concerns economics. No matter how good we feel a plant may be, it is of little value unless the customer wants it. Customer demand can be created by marketing and promotion or by merely the appealing appearance of the plant in the landscape or sales area. It is this potential for large economic gain that seems to be creating the desire among many nurserymen to grow many new cultivars.

THE ROLE OF TISSUE CULTURE

With the advent of improved propagation techniques, primarily tissue culture, the "normal" plant introduction cycle seems to have been shortened from years to mere months. The tissue culture process, which became economically feasible less than 10 years ago, appears to have been the catalyst in making a plethora of cultivars at relatively low prices in large quantity all available at once. Many cultivars currently offered for sale are new or have been previously available only in limited quantities. The market among growers for these new improvements seems to be nearly insatiable even in those types not yet produced by tissue culture techniques.

There also seems to be a change occurring among growers that causes them to alter their previous conservative approach to trying new plants. Perhaps the sheer number of new cultivars being promoted or specified by landscape architects contributes to this increase of interest. Retail customers may also be asking for better or more interesting landscapes. The upsurge of interest in new cultivars by members of specialized plant societies has probably additionally contributed to it. Whatever the reason growers have become far more willing in recent years to take a chance with new introductions.

THE PROBLEM

In our haste to meet the anticipated demand for new cultivars, many propagators appear to be compromising the normal quality-evaluation stage of product introduction. This dangerous trend is manifested both in the *methods* we use to choose which new plants to grow and in the propagation process itself.

Some of our methods call for serious examination. Part of the problem is that our industry is hampered by the difficulty and complexity of properly testing the product before it is released. Today's fast-moving market no longer allows the extensive evaluation previously afforded new introductions. How extensively has the new cultivar been tested to determine that it is better than its counterparts already on the market? Should we predicate our decision to produce a new plant on evaluations by only the introducer himself? How many years has the plant been available for evaluation? Who are the evaluators? What is the criteria for evaluation? What are the drawbacks as well as the advantages of the new cultivar?

We propagators have always wanted to share our new plants with each other because we consider ourselves part of the "same big family". This feeling of mutual trust can be undermined when motives other than pure horticultural interest begin to assume a higher priority. Unbridled enthusiasm can lead to hasty decisions which adversely affect our ability to make good judgements. Some people lose sight of the intent of the hybridizer and try to do more with the new plant than is practical. But worse than these relatively innocent problems are the purposeful actions motivated by a selfish business person who tries to take advantage of the work of others for unreasonable personal gain. Even though we see far less of this latter activity in the nursery industry than in other industries, it has ominous potential to override the very personal trust upon which our industry is predicated.

This type of ethical transgression can occur any time a hybridizer distributes plants outside of his own operation for testing and evaluation. The fact that the plant is being evaluated in a normal growing site means that it is accessible to other people and that the hybridizer no longer has control of it. Hybridizers have attempted to reduce the risk that others will propagate their cultivars by selecting evaluators carefully, by using codes rather than names, by patenting or trademarking the cultivar, or other techniques. Most of these methods are less than totally effective in preventing premature distribution. And in many cases it is excessively expensive to do these things, especially when more than a small number of cultivars must be evaluated. But as serious as the potential is for problems, most hybridizers and evaluators have avoided major catastrophe by maintaining a high measure of personal involvement. As of yet the distrust and secrecy so prevalent in other industries does not appear to have gained a foot-hold in the nursery industry.

The process of propagation itself also poses some perplexing problems. As difficult as it is to identify cultivars of similar plants in normal propagation, it is nearly impossible in the early stages of tissue culture. Because such large numbers of plantlets are produced from so few pieces of the parent plant, a mistake in choosing the stock plant can result in thousands upon thousands of improperly-named plants being distributed before the error is discovered.

There also seems to be some evidence of increased probability of mutations or changes in characteristics of some plants produced from tissue culture. Thus, if the new introduction proves to be different than expected, the grower must rely more than ever on the integrity of the propagator.

OBLIGATIONS TO OUR CUSTOMERS

The nursery industry, if it is to retain the credibility we have created over the years in the minds of our customers, must satisfy certain expectations. Our products must be true-to-name and perform as we advertise and as our customer expects. The plants we sell must perform well in the landscape with reasonable care. We must avoid confusing our customers with too many choices lest we drive them to purchase easier-to-choose products. We must insulate our buyers from our own errors such as overproduction, an inferior product, or a poor value.

The consequences of failing to meet these obligations will be unfortunate for our entire industry. In the short term we will encounter disappointed customers, contend with annoying complaints and costly replacements, and begin to increase the skepticism of our products in the minds of the public. The longer term will cause our customers to move away from unrewarding purchases and begin to develop a distrust of new plant introductions, even truly worthy ones. The end result may well be an unwillingness of our potential customers to trust many of the services we perform and even perhaps to demand stricter regulation by government of our activities.

THE PROPAGATOR'S OBLIGATION

I see several actions we must take as plant propagators to protect ourselves and our industry against an erosion of credibility in the mind of the public. These needs apply to all the plants we propagate but are particularly critical in regard to new introductions.

First we must develop, use, and respect industry standards for evaluation and testing of improved cultivars. Many plant societies already are using some criteria as are some arboreta, universities, and plant introduction stations. The "All-America" program seems to have many appealing aspects. But even private and individual hybridizers and selectors must have evaluation standards and guidelines by which to begin to judge the merits of their selections.

Second, as propagators we must insist upon the trueness of our stock before we propagate it. We must stand behind the claims we make and be absolutely sure of our source. We must have the ability to test our propagations ourselves before distributing, and refuse to let inferior selections get to the market. And I believe that to prove our commitment we must be willing to buy back any mistakes that we make by distributing wrongly named plants.

Third, before advertising and promoting a plant, we owe our customers the assurance that such plants are available to them in reasonable quantities. Plant material is not an "off the shelf" item, particularly in landscape sizes. This process requires a major production commitment and knowledge of the marketplace as well as utilization of proper channels of distribution.

Lastly, we owe our customers (and ourselves as well) the obligation to control the urge to overproduce. The familiar cycle of overproduction and shortages that plagues our industry results in destabilizing market fluctuations of availability and price. Nothing can be as frustrating to a customer as discovering the cultivar that was in such good supply last year is scarce and over-priced this year (or vice-versa). This problem can be solved with proper planning and effective product management programs in our own businesses.

I would like to introduce our panel and ask each of them to share their concerns and ideas on plant introductions. Each of them has a strong commitment to a different aspect of the nursery industry. Each as been involved with selecting, introducing, and selling new cultivars.

MAINTAINING CREDIBILITY IN PLANT INTRODUCTIONS II

JIM CROSS

Box 730

Cutchogue, New York 11935

For the past 20 years our small nursery, which grows woody ornamental plants for the wholesale market, has been deeply involved in a continual process of building and maintaining a product line consisting primarily of relatively hard-to-find plants. Our selection criteria gives heavy emphasis to dwarf and slow growing plants. The majority of our ornamental plants are not "new" selections, just known but neglected plants.

The very nature of the selection process that we followed up to the advent of micropropagation provided a pace and built-in discipline, which helps assure a fair amount of test and evaluation time in the climates into which we market our plants. The typical starting point would be a single, small plant or a half dozen cuttings, a couple of progeny of which would go into the garden or stock area for observation. If, over the next few years, we liked what we saw, we would run a couple of dozen plants through our production system to see how they performed. By the time we moved to a trial crop of 100 to 200 plants, there has been a lot of time to communicate with others who have had experience with this plant, to evaluate its ornamental qualities in our climate, to test garden culture, to test its adaptability to the nursery production process, and even to test market through friends and customers and a few customers of our customers.

This procedure, with its very moderate pace, contrasts quite sharply with what we are beginning to witness in these early years of woody plant propagation by tissue culture. There is something tion to control the urge to overproduce. The familiar cycle of overproduction and shortages that plagues our industry results in destabilizing market fluctuations of availability and price. Nothing can be as frustrating to a customer as discovering the cultivar that was in such good supply last year is scarce and over-priced this year (or vice-versa). This problem can be solved with proper planning and effective product management programs in our own businesses.

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This procedure, with its very moderate pace, contrasts quite sharply with what we are beginning to witness in these early years of woody plant propagation by tissue culture. There is something about the excitement and romance of a new area of knowledge which causes an otherwise quite learned, experienced, and stable person to forget hard-learned rules and trip over their feet in their haste to get on with it. In our haste we create more problems than we solve. If that is the case, we fail to progress and, in fact, may unnecessarily go backwards. We need seriously to adjust our attitudes and the procedures that we are currently developing in tissue culture propagation. If today's session achieves only one thing, the stimulation of our thinking to the point where we moderate the excessive swing of the pendulum under its own momentum, our time here will have been well spent.

For those who may not think that we have a significant problem, a review of a few simple facts should suffice.

Nomenclature is perhaps the sector of most damage to date. Because of the ease of making serious errors with the large numbers being widely and rapidly disseminated, we have a real monster by the tail. Mistakes in these early years of tissue culture will not be erased in the next decade even with conscientious effort. I suggest that the first 5 years of woody plant tissue culture may have created more misnamed plants than the total of such mistakes in the entire post World War II era. At one time in our nursery we had, just by chance, six evergreen rhododendrons propagated by tissue culture sitting side-by-side. It turned out that one-half, three of the six, carried completely erroneous names. The record with the deciduous rhododendron hybrids was not much better. Many growers who purchased these plants do not know to this day that the name is wrong. There are probably one or more who will continue to distribute these plants under an incorrect name for the rest of their days.

One of the great potential advantages of tissue culture is an improvement in the quality of the individual plants. This is especially pronounced with rhododendron where elimination of that open, leggy, young rooted cutting is really exciting. Here too, the new problems created from too much haste may well offset the hoped-for advantages. We have in our nursery a crop of tissue-cultured *Rhododendron* 'Molly Fordham', with every other plant containing witch's broom type growth with no normal foliage. A couple of month's back, I brought back from a visit to a neighboring nursery, three plants with very distinctly different leaves and rates of growth all selected from a large batch of tissue-cultured *Rhododendron* 'P.J.M.' Had I taken more time to make careful comparisons, I probably could easily have doubled the number of variants. We have a couple of beautiful crops of a dwarf rhododendron from tissue culture which give every indication of not having a gene to tell them to produce flowers. These plants, with which we have long been familiar, have grown too long to attribute the lack of flower buds to juvenility.

In the case of *Kalmia latifolia,* we see a big difference in consistency of quality between seedlings and the many nice tissue-cultured clones. Many of the latter have a high percentage, like ⅓ to ⅔, of discards because of inadequate root systems. These can be kept looking fairly good in the wet regime of a container nursery but they will not establish in the garden. There has been a great difference in response from clone to clone. A growing medium for protected indoor conditions which has resulted in excellent crops of seedlings year after year will grow beautiful *Kalmia latifolia* 'Carol' from tissue culture plants but will cause serious leaf damage and drop after every flush of *K. latifolia* cultivars, Sarah and Nancy. Incidentally, we have at least two distinctly different plant types in the remains of our 'Sarah' crops. We have a lot to learn about the basic procedures but, under the current system, the people who are learning what is wrong are not the ones who can undertake correction.

We badly need to adopt different attitudes at every level of our procedures. The plant breeder or finder is acting just like before micropropagation; casually passing along pieces of propagation wood of a new plant of current interest without thinking much about the real consequences when it goes to a tissue culture lab. The plant originator must somehow continue to obtain the help of others in testing and evaluation but without the risk of premature propagation in large quantity. This person must also take extra care to make certain that a good clear label goes out with every piece of wood. Not only are time and quantity to be considered but, with tissue culture, we will typically have involved people without wide knowledge of the plants being multiplied.

The manager or decision maker at the tissue culture laboratory has been assuming that, if he is given a piece of wood, it is O.K. to propagate real numbers without further authority. Most times it is also assumed that this plant has already been tested and passed on by that very knowledgeable and experienced plant breeder (or he would not have been given the wood). It has also been assumed that, if a plantlet develops from the lab's effort, it is a healthy duplicate of the parent.

The tissue culture lab has to exercise a greater sensitivity to the importance of several of its logical responsibilities:

1) as to the status of the potential product.

2) as to the weaknesses inherent in such a new, still being tested, process. There is a need to understand exactly what is being produced and sold before it is shipped out.

3) as to assuring proper names.

In addition, the lab should assume some responsibility for judging the ultimate demand for a given plant and the correspondingly appropriate production. A national market is being served and no one else knows just how many plants are being produced.

Lastly, the grower or buyer assumes the purchase of a good, well-selected and well-tested plant, or it wouldn't be offered for sale. Each of the different levels of the system seems to be falling into the trap of shifting the final responsibility for this evaluation function to another level. The grower needs to be more thoughtful in this matter. Also there is a need to apply more common sense in trying out new items. The process makes it a bit too easy to move faster than one should. The glamour of the new items and the low cost of an initial start tends to undercut those parts of the process which normally would provide resistance to buying in more than a grower.

The old system sort of took care of many of these potential problems over the more considerable span of time involved. We will benefit greatly from the advantages of tissue culture if we all apply our very best efforts to correcting these basic flaws. I believe that this can be done simply by taking the time to put to work what we already know.

MAINTAINING CREDIBILITY IN PLANT INTRODUCTIONS III

RICHARD A. JAYNES

Broken Arrow Nursery
13 Broken Arrow Road
Hamden, Connecticut 06518

First, let me give you a little background. I was trained as a botanist, worked for 25 years at the Connecticut Agricultural Experiment Station as a plant breeder and horticulturist, and since 1984 have been a self-employed nurseryman and Christmas tree grower. I have selected and bred mountain laurel (*Kalmia*) for 27 years and am responsible for naming about half of its new cultivars. I also serve as the International Registrar for the genus. So, if you are naming and releasing a new mountain laurel, let me know.

I am delighted to serve on this panel because I find I have somewhat ambiguous thoughts on naming and releasing new plants. On an intellectual level I am conservative and would argue for thorough testing before release. However, in the real world I am more pragmatic and, quite frankly, have been willing to release material without acquiring some of the information it would be nice to have.

The criteria for selecting and naming a new cultivar is going to vary somewhat depending on the genus, the number of cultivars no one else knows just how many plants are being produced.

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The criteria for selecting and naming a new cultivar is going to vary somewhat depending on the genus, the number of cultivars already named in the group, the uniqueness of the selection, ease of propagation and production, and perceived demand in the market place. Fifteen years ago you could not give away new *Kalmia* selections for propagation. Twelve years ago there were virtually no newly named *Kalmia* cultivars; however, numerous unique and attractive selections were available, tissue culture of Ericaceous plants was just beginning in earnest and there was a perceived, growing demand for mountain laurel in the market place. The result has not been too surprising. In the past 12 years we have had a mini explosion of 45 new cultivars introduced, with the count steadily increasing.

Do we need all these cultivars? Not really.

Will more be named? Most certainly.

Was it a mistake to name so many? No, each was justified in its time. The chance of uncovering some truly great selections is increased by thoroughly testing many superior plants, i.e. the newly named releases.

What is justified? A new selection should be clearly superior to other previously named cultivars in one or more traits and there should be a potential market for the plant. When and how we judge "superior" is a problem.

What criteria do I use to name a new selection? Typically a new selection will come from a field of several hundred other mountain laurel seedlings all grown from controlled crosses. In addition to the seedlings in the field, it will also be compared to already named cultivars. The new plant must be clearly superior and unique. It should jump out at you. If it takes a hand lens to see the difference, forget it. It is observed for at least 3 years after initial selection to confirm the initial judgement, whether the trait is floral, foliage, plant habit or something else. The opinion of others is solicited and definitely considered.

My new selections at the time of release have generally not been tested in climates other than that of the nursery, they have not been container-grown, nor have they been rigorously screened for common disease and insect problems. Such screening is desirable but may not be practical. It would certainly delay release by several years.

A profusion of new selections is not all bad. Sure it creates confusion, but it also creates interest. It becomes a contest to select and grow the best of what is being made available. If the system works properly the best cultivars will be the survivors until they are replaced by another generation of even better ones.

The following are some of the advantages or reasons *not* to spend too many years on screening a new selection before it is released under name:

1) Plants sent out under number or code receive scant attention at most nurseries or institutions.

2) Through micropropagation immediate demand can be satisfied without a long delay. After 5 to 10 years of additional testing it may be difficult to rekindle that same demand.

3) The marketplace is the ultimate and final testing ground. The winners and losers will actually be sorted out more quickly in the marketplace resulting in better cultivars sooner.

4) Plants held too tightly and too long by an individual or institution may die with that individual or disappear with termination of a program.

Of course, none of this relieves us from the responsibility of being very honest in our claims for the virtues of new selections. It's a little like during your dating years with a new girl friend or boy friend, they may look good but it takes a lot of time and experience to determine their real worth. So it is with plants, we need to be very selective in naming and introducing new plants, but not so cautious that we are afraid of a few failures.

Let me try to summarize my thoughts on the release of new plants. Be as convinced as you can that the selection is better than anything else in the marketplace. Do not rely on one year's observations. Tout its merits when released but do not make unwarranted claims.

And for those of us purchasing and growing new releases, it behooves us to not commit too heavily until we are quite certain that the plants will perform up to expectations.

MAINTAINING CREDIBILITY IN PLANT INTRODUCTIONS IV

WILLIAM FLEMER III

Princeton Nurseries
P.O. Box 191
Princeton, New Jersey 08540

In considering the introduction of a new plant to the nursery trade, the first qualification must be that the new plant is recognizably different from existing clones or cultivars and genuinely superior to them. There is really no point in introducing a new plant which duplicates ones already established in the horticultural world. If, for example, I were to find yet another witches' broom on Norway spruce (*Picea abies*) I would not consider growing it and offering it for sale because there are already over 60 clones which were described and grown in the past, a large number of which are identical from a horticultural point of view, and the chances of coming up with a really superior clone are remote.

A corollary of this principle is to avoid too many new clones of a given species or group of hybrids. Plant breeders are like the proud

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A corollary of this principle is to avoid too many new clones of a given species or group of hybrids. Plant breeders are like the proud parents of many children. Far too often each new creation has special merit and distinction (no matter how small) and the result is a needless and detrimental proliferation of new clones. A clear example of the hazards of introducing too many clones is the family of Glenn Dale azaleas, which were hybridized and introduced by B. Y. Morrison from 1947 to 1952 while he was the Director of the United States National Arboretum in Washington, D.C. In total 442 clones were named and introduced, as one humorist stated—using up wastefully all the possible azalea names in the English language! With such an over-kill of new clones, they were essentially ignored by the professional azalea growers and have passed into oblivion. In contrast, the Delaware Valley Nurseries introduced only one highly superior cultivar, Delaware Valley White, which is now the standard in the trade, by which all other white garden azaleas must be judged.

An additional fact which must be recognized is that there is no ideal cultivar which is the best throughout the entire country. The United States is an enormous continent with a range of climatic zones from Zone 10, where it never freezes, to Zone 2 where winter temperatures of −35 to −50°F are commonplace. Temperature is only part of the story, however, because there are extremes of humidity and rainfall from the humid East and the rain forests of coastal Washington state to true deserts where rainfall is extremely rare. Soil pH also varies from the extreme acidity of bogs and conifer forests to the highly alkaline soils of the mid-western states. For example, *Acer rubrum* grows wild from Canada (Ontario and the northern tip of Nova Scotia) to the Florida Everglades. The cultivar October Glory is not reliably hardy in northern Minnesota, and 'Northland' is inferior to ordinary red maple seedlings in New Jersey. Similarly the hybrid crab apple 'Radiant' is a superb red cultivar in the low humidity areas of the Midwest, but defoliates in humid summers on the East Coast. Consequently there is a need for the best clones for a variety of climatic and soil zones.

An essential part of any program of plant breeding and introduction is testing the new clones before they are commercially introduced. A new plant should be tested for its performance in the landscape and on city streets if it is a shade tree. Prior to such testing it should be grown in the nursery for many years and evaluated for insect and disease resistance, growth habit, winter hardiness, and reasonable ease of propagation, as well as other criteria. A new shade tree obviously cannot be tested for its potential 50 to 100 years of life expectancy or none would ever be introduced. Our new trees at Princeton are routinely grown and tested for decades before they are finally introduced, and this makes tree breeding a very slow process indeed. We find that there are a few municipalities which are willing to test new trees under actual street conditions and we value their input enormously. We are less enthusiastic about tree evaluation in arboreta and botanical gardens after some unhappy experiences in which our new trees were planted between and under two or more mature trees of that genus and then received unfavorable reports as being "weak growers".

A country as big and varied as the U.S.A. cannot have a nationwide evaluation program like the Royal Horticultural Society trials in England, because so often it would be a contest between "apples and bananas". Our best route is to institute regional evaluation programs like The Styer Awards of the Pennsylvania Horticultural Society which judges new plants for their garden merit under East Coast conditions. The program has already generated considerable prestige in our area.

In conclusion, maintaining credibility in plant introduction depends ultimately upon the integrity of the introducer who should be a severe critic of his own creations and introduce only a few of the very best of his new clones.

RUTH KVAALEN: I would just like to make a plea for any person who is going to introduce a new cultivar to first contact the registration authority and get the name registered. This is important because it is impossible for registration authorities to go through nursery catalogs and hunt up new cultivars. Registration will allow you to determine if the name has been previously used and also prevent anyone else from using that name. If you do not know who the registration authority is, the American Association of Nurserymen can tell you.

NINA BASSUK: I have a few comments. I applaud the increase in diversity of our plant materials. In our work we are interested in looking at plants for urban areas and are developing protocols to actually rate plants for differences in environmental tolerances. I would like to see new introductions rated for urban adaptations.

DEB McCOWN: I have a comment. Many tissue culture labs have attempted to micropropagate plants that are difficult to propagate by conventional methods so that we can put them out for evaluation and obtain more information. I would cite *Kalmia* as an example.

BILL FLEMER: I have a comment on recommended plants not being available. We have a system in New Jersey that has worked quite well. Shade tree commissions have arranged ahead of time with a wholesale grower to contract-grow certain plants for their uses. This has worked well for certain clones or unusual species of plants. A nursery has to have a reasonable number of trees contracted for to make it worthwhile.

GARRY KOLLER: One problem I have always had with evaluations is, what you look for in a plant. This is a problem because we all have different wants and needs. I am afraid that what we are looking for in many new introductions are minute differences rather than substantial market niches that will sell plants. Many of the differences we look for are not marked enough to be worthy of introductions.

Thursday Afternoon, December 10, 1987

The afternoon session was convened at 1:30 p.m. with Chris Graham serving as moderator.

RED OAK WHIP PRODUCTION IN CONTAINERS

DANIEL K. STRUVE

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Abstract. A system is described whereby the equivalent of 1-year-old red oak whips can be produced in 7 months, starting from seed.

INTRODUCTION

Currently red oak whips are produced as follows: In the first year, seeds are sown in fall or spring. The resulting 1- or 2-year-old seedlings are dug from seed beds and lined out in field rows. If the liners produce more than 18 in. of new growth the first season, they are cut back to 2 in. in height the next spring. If growth following lining out is poor, the cutting back is delayed one year. After cutting back the most vigorous young shoot is selected and trained vertically, resulting in 5 to 8 ft whips by the end of the growing season. Hence, the present whip production system requires 3 to 5 years to produce a 1-year whip.

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INTRODUCTION

Currently red oak whips are produced as follows: In the first year, seeds are sown in fall or spring. The resulting 1- or 2-year-old seedlings are dug from seed beds and lined out in field rows. If the liners produce more than 18 in. of new growth the first season, they are cut back to 2 in. in height the next spring. If growth following lining out is poor, the cutting back is delayed one year. After cutting back the most vigorous young shoot is selected and trained vertically, resulting in 5 to 8 ft whips by the end of the growing season. Hence, the present whip production system requires 3 to 5 years to produce a 1-year whip.

Starting from seed, the system described in this paper can produce the equivalent of a 1-year whip in seven months. Seeds are germinated and container-grown under greenhouse conditions for 10 weeks. They are then acclimated to outdoor conditions for 2 weeks, up-canned and grown for the remainder of the season under standard container growing practices. The system combines the Accel-O-Gro concept (4) with growing plants in copper-treated containers (1,2,3,5,7).

Container production systems for oak have been described previously (5,8). However, these systems used greenhouses or polytunnels for the entire production cycle, where the present system uses greenhouse facilities for only the first 10 weeks.

SYSTEM DESCRIPTION

About March 1, red oak seeds were broadcast in flats on moist peat moss and the flats placed under intermittent mist for seeds to germinate. Germination uniformity can be increased by previously soaking the seeds overnight in tap water. When the radicles are at least 1 cm in length, the seeds are sown 1 cm deep in one gallon round plastic pots and covered with growing medium: pine bark: sand: peat moss (3:1:1,v/v/v). Containers were placed pot to pot at approximately 15 cm (6 in.) square spacing on greenhouse benches. Once the seedling shoots have emerged, a medium-saturating soil drench of micro-nutrients (S.T.E.M. at 170.4 g/22.7 liters of water (6 oz/5 gal), Peters Fertilizer Products, W. R. Grace and Co.), and 16 g (1 tablespoon) of 18-6-12 Osmocote (Sierra Chemical Co) was applied to each container. Once per week the plants were fertilized with 200 ppm N from 20-20-20 water soluble fertilizer (Peters Fertilizer Products).

The plants were grown under the following conditions: natural daylight supplemented from dusk with 45 to 60 $\mu mol/sec^{-1} 1/m^{-2}$ PAR from high pressure sodium lamps to give a 20-hr photoperiod, temperature set at 25/19°C day/night. Plants were watered as needed. Research conducted in 1987 showed that similar sized plants could be produced without the extended photoperiods of high intensity light (Chinery, unpublished data).

The inner container surfaces were painted with a mixture of 100 g $CuCO_3$/liter white latex paint and air dried before seeds were sown. The $CuCO_3$-treated surfaces inhibit root elongation upon contact (1). This eliminates the need to root prune to correct root system deformity caused by matted, kinked, or circling roots.

On May 15 (the last frost date in Columbus, Ohio) plants were transferred to 70% shade in the outdoor container growing area. After a two-week acclimation period the plants were repotted to 5 gallon fiber containers (Kord Products Limited, 390 Orenda Road, Bramalea, Ontario L6T 1G8). The 3R1109 fiber pots were specially formulated to control root growth in a manner similar to the $CuCO_3$-

treated plastic containers used previously. The same pine bark:sand:peat growing medium was used. After up-canning, the plants were placed in full sun on 41 × 46 cm (16 × 18 in.) spacing. The plants were given a second soil drenching with micro-nutrients and 32 g (2 tablespoons) of 18-6-12 Osmocote was added to each container. The plants were fertilized weekly with 280 ppm N 30-10-10 water soluble fertilizer (Plant Marvel, Chicago Heights, IL). Plants were staked to promote the development of a straight central leader and lateral buds were pinched off until plants reached 5 ft in height. Throughout the production cycle insect pests were controlled using commercially recommended sprays. In 1987 83% of the plants transferred from the greenhouse to the container area were ≥ 100 cm (3¼ ft) and 47% were ≥ 150 cm (5 ft) by September. The tallest plants approached 8 ft in height (Figure 1). To encourage caliper growth stakes were removed in September. Stem caliper ranged from 1 to 2 cm (½ to ¾ in.).

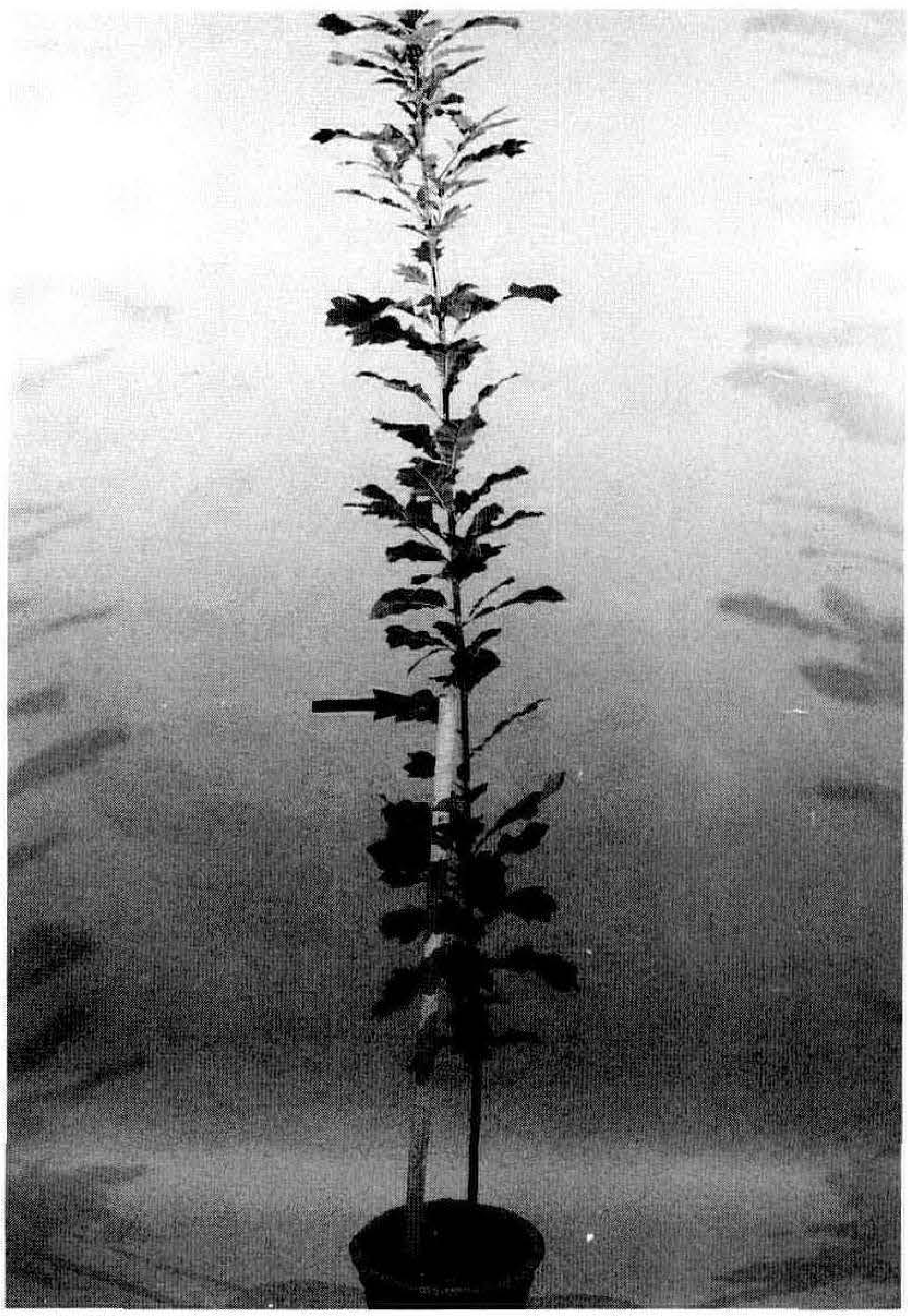

Figure 1. Red oak grown from seed to 8 ft height in 7 months under the conditions described in the text. The container is 13 in. diameter. The top of the meter stick is indicated by the arrow.

REGROWTH POTENTIAL

Red oak whips produced in containers in 1986 were field-planted in October, 1986. Plants were spaced 1.2 m within rows and 3.9 m between rows (4 × 10 ft). In March, 1987, overwintered container-produced whips were planted at similar spacing. At the same time 5 ft bareroot red oak whips were planted. In total, 120 container-grown (90 fall-planted, 30 spring-planted) and 30 bareroot whips were planted.

All plant material produced one flush of growth during the dry (April to October rainfall averaged 6 to 9 in. below normal) 1987 growing season. The plants received no irrigation. Container-produced whips averaged 45 cm (18 in.) of shoot growth, while bareroot stock averaged 15 cm (6 in.). No container produced whips were lost during 1987. Five bareroot whips were lost.

REASONS FOR RAPID GROWTH

The rapid growth can be attributed to extending the growing season and eliminating transplant shock. Plant growth is exponential: i.e. the amount of growth a plant can produce is dependent on present plant size. By starting the seedlings in a greenhouse, 10 extra weeks are added to the growing season. Although seedlings are not large at the end of the 10-week greenhouse production phase, great dividends are paid at the end of the growing season (Figure 2).

Copper-treated pots eliminate root pruning to correct root system malformation. When roots contact the copper-treated surfaces root elongation is inhibited, and circling, matted, and girdling roots do not develop. However, root regeneration potential remains high once the copper-treated container is removed for transplanting. Within 3 to 6 days root elongation resumes at rates similar to roots which had not contacted copper treated surfaces (1).

In one study root pruning to correct root system malformation removed up to 75% of lateral root dry weight in green ash and red oak (1). Root-pruned plants also had lower root regeneration potential and reduced shoot growth compared with non-root-pruned plants grown in copper-treated containers (1).

BENEFITS OF CONTAINER-PRODUCED WHIPS

The system described for production of containerized red oak whips has several advantages over present production techniques:

1) Plants can be marketed more effectively. Orders for fall or spring delivery of 1-year-red oak whips could be taken until March of the year of production. Typically, orders are booked 3 years in advance, the minimum production time.

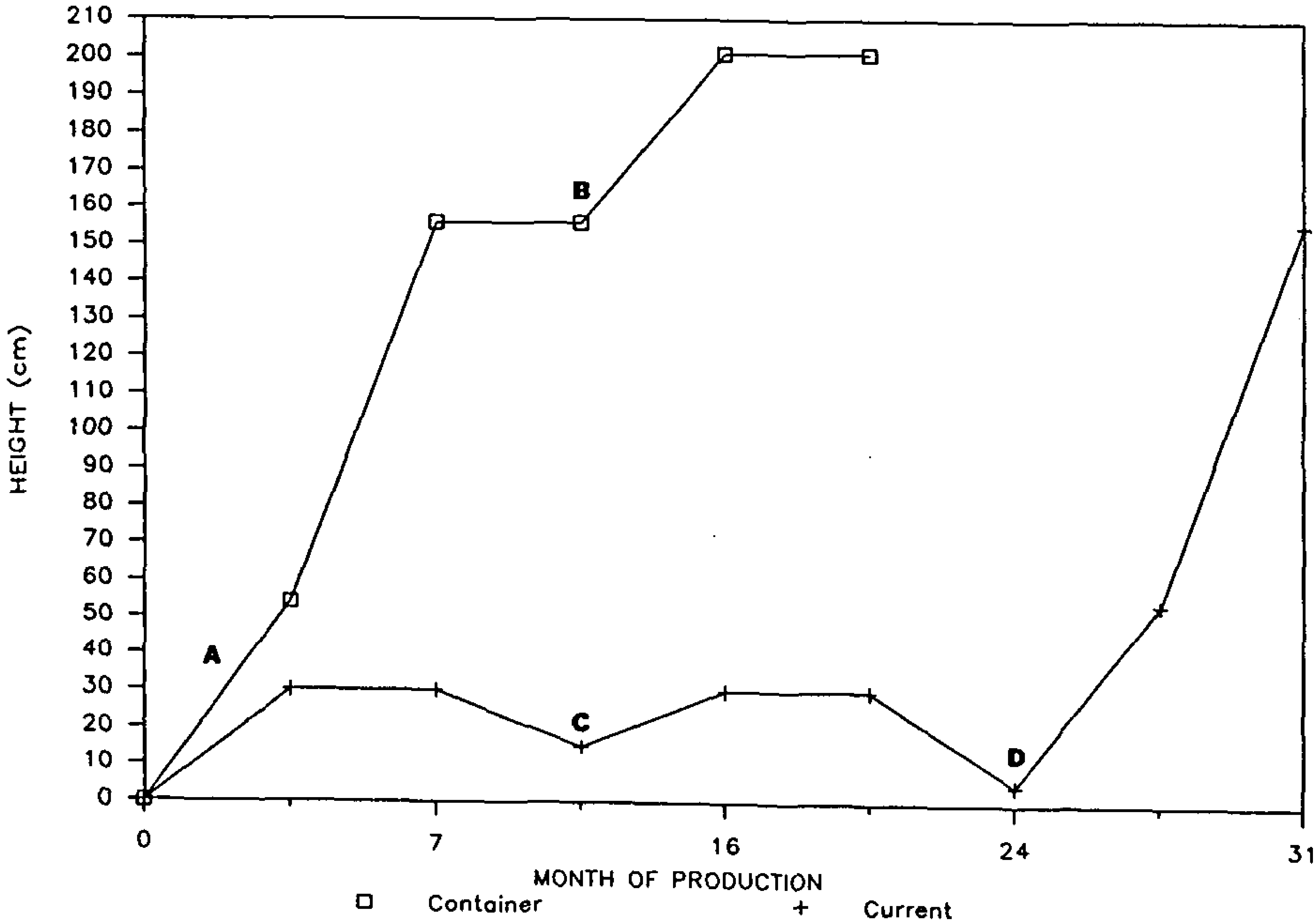

Figure 2. Growth of red oak whips produced under conditions described in the text (□) and under typical production practices (+). "A" is the point where seedlings are transferred from the greenhouse to the container production area, "B" is the point where container grown whips were transplanted to the field, "C" is the point where 1-year-old seedlings are pruned and lined out in the field and "D" is the point where the lined out stock is cut back and whip training begins.

2) Production efficiency is increased. Only enough acorns to cover orders for whips need to be sown (with an additional allowance for grade-out or speculation), thus avoiding speculating on market conditions 3 to 5 years in the future.

3) The container-produced whips have high root regeneration potential, allowing for rapid establishment upon field planting or up-canning. We expect to be able to produce 1½ to 1¾ in. caliper red oaks within 4 years, starting from seed.

4) The system can be used to grow other oak species and other genera (i.e. 8 ft 'Autumn Flame' red maple were produced in 7 months starting with 4 in. tall rooted microcuttings).

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ETIOLATION TO IMPROVE SOFTWOOD CUTTING PROPAGATION: ASPECTS OF HORMONE APPLICATION AND TIMING OF TAKING CUTTINGS

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Abstract. The research presented here focuses on the factors affecting hormone application and timing of taking etiolated cuttings, with the goal of developing etiolation and banding into practical methods for use by the plant propagator. Etiolation was found to be more beneficial than banding when applied to 4 cultivars of *Fagus sylvatica* and 2 of 4 cultivars of *Acer saccharum*. In experiments with 2 cultivars of *Syringa reticulata*, banding, with or without etiolation, was most beneficial in stimulating rooting. The treatment of *S. reticulata* cuttings with 4000 ppm IBA was of little additional benefit. Conversely, cuttings from etiolated shoots of *Stewartia pseudocamellia* rooted best, the effect still evident after 2 months greening. Hormone applied at sticking was of a significant benefit to the rooting of *Stewartia* cuttings.

INTRODUCTION

Etiolation is a process which involves growing shoots in the dark. This technology has had a place in the efforts of plant propagators to improve the rooting of softwood cuttings since F. E. Gardner reported in 1937 on his success in rooting etiolated apple cultivar cuttings (4). In the past 50 years perhaps the greatest contribution toward developing etiolation and its related technique of banding into methods of practicality to the nurseryman has been made by Howard and co-workers at the East Malling Research

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Station, Kent, England. We, at Cornell University, have followed over the last five years a similar tack toward developing etiolation and banding as practical methods for the softwood or semi-hardwood cutting propagation of difficult-to-root woody plant species. In this time we have greatly expanded the list of ornamental tree species which may be successfully rooted using etiolation. Furthermore we have worked with the techniques of etiolation and banding so that they are now simple and productive components of the vegetative propagation program at Cornell. As an improvement to Gardner's method of using black tape or paper we have developed the use of Velcro adhesive strips as a banding material. What we now have is a more effective banding method requiring less effort and allowing for the application of a root-promoting hormone [usually indole-3-butyric acid (IBA) in a talc base] to intact stems. Using hormone-laden Velcro we are able to promote callusing and even root initiation in a way similar to, but much easier and faster than, air layering. Previous results have been reported to this Society (1, 2, 6) and in the American Nurseryman (7).

The usefulness of etiolation and banding in improving the success of cutting propagation has been proven in the propagation of a number of species including maples, birches, hornbeams, chestnut, pines, hazelnut, and six cultivars of common lilac (*Syringa vulgaris*). Questionable initial results have been obtained at Cornell *only* with *Acer platanoides, Quercus rubrum,* and *Q. palustris* (6). We have a number of reasons for continuing a very active research program on the use of etiolation to improve rooting. First, there continues to be a large number of woody plant species which cannot be rooted at all, or only at very specific times of year (i.e. 'windows of rooting'). Also, problems still exist with graft incompatibility (e.g. *Psuedotsuga menziesii, Quercus palustris* 'Sovereign', and *Acer rubrum* cultivars), or poor "take" (e.g. budded *Acer saccharum*) (3). The relatively high labor costs and lengthy production times associated with grafting/budding could also be avoided were cutting propagation possible. Non-vegetative propagation (i.e. seed) is subject, of course, to genetic variability and to dormancy problems, resulting in poor or inconsistent cropping (5). Finally, though micropropagation may eventually replace all other means of cloning plants it is probably safe to assume, because of the cost, technological prerequisites, and problems with somaclonal variation, that there will always be a place for the cutting propagation of woody plants.

There is good evidence that etiolation serves to extend the "window of rootability" (1), that period of weeks, or perhaps only days, when a species may be rooted successfully, which is flanked by extended periods of poor rooting. Futhermore, we commonly observe that previously etiolated cuttings root readily, often in as little as two weeks. This allows for the rooting of cuttings earlier in the growing season, resulting in improved overwintering and the production of finished plants in as little as one-half the time needed to produce a finished plant from budded stock. This shortened production time combined with the ability to take cuttings over a greatly lengthened "window of rooting" means that a tremendous potential exists for increasing production of desirable plant materials.

At present our research efforts are geared toward improving the technology of etiolation and banding, and toward understanding what processes are at work in generating the improved rooting responses of treated cuttings. We are investigating the timing of treatment and of the taking of cuttings to discern the precise effect of etiolation on this "window of rooting". By studying the optimum number and strength of hormone applications we will determine the conditions producing the fastest rooting response in the propagation bench. Each season we continue to expand the number of species propagated using etiolation, and welcome suggestions of other species we might try. And we are studying the aftercare of cuttings, such that etiolation technology may be adapted completely to the nursery production situation (2). Finally, we are looking closely at the changes occurring in etiolated or banded stems, anatomical and physiological, which might explain the root-promoting response to etiolation. Recent research results relating to the aforementioned objectives are presented in this report.

MATERIALS AND METHODS

The etiolation and banding technique has been presented in detail elsewhere (7). Briefly, field-grown or containerized dormant stock plants are covered at bud break with an opaque material, usually black cloth or plastic (about 95% light exclusion); taking care to allow space for the new growth to extend. Initial growth is allowed to proceed in the dark (etiolation) until new shoots are between 5 and 7 cm long, after which time the shade is gradually removed over the period of one week so as not to scorch the very tender shoots. On the first day of shade removal, Velcro strips approximately 2.5 cm wide by 2.5 cm long are placed at the base of each new shoot (the future cutting base). A rooting hormone (8000 ppm IBA in talc) is added to the Velcro before banding the shoot. Both pieces of Velcro are dipped in the talc preparation; the excess powder is tapped off, and the Velcro band applied firmly to "sandwich" the shoot. Velcro bands are left on the shoots for about 4 weeks, after which the cuttings are removed from the stock plant below (proximal to) the banded area. The bands are removed and the cutting bases are again treated with hormone (4000 ppm IBA in 50% aqueous ethanol) before sticking them in the rooting medium. The rooting medium consists of peat and perlite (1:1, v/v) with bottom heat (25°C), overhead mist, saran shading (50%), and a 16 hr photoperiod supplied by 60 watt incandescent bulbs hung 1 meter above the bench. Cuttings are left in the bench for 2 to 5 weeks. After rooting, the cuttings are potted up, weaned from under the mist, fertilized, and kept under long days (16 hours) to encourage growth.

Blanching is accomplished by banding shoots as described above, except that stock plants are not initially covered, so new growth develops in the light. The hormone-coated Velcro is applied when the soft, green shoots are 5 to 7 cm long.

The *Fagus sylvatica* clones with which we experimented were established plants approximately 15 years of age and located in the Cornell Test Gardens. The four *Acer saccharum* and two *Syringa reticulata* cultivars, plus stock plants of *Stewartia pseudocamellia* were kindly donated by George Schichtel of Orchard Park, New York. These plants were 3 to 5 years of age.

RESULTS AND DISCUSSION

***Fagus sylvatica* cultivars:** The four European beech clones were treated in the field in the spring and summer of 1986. Banding alone was not beneficial in improving the rooting response of any of the four beech clones tested (Table 1). However, when etiolated shoots were banded to maintain etiolation, significant increases were obtained with the species clone (i.e. not a named cultivar), and the cultivars, 'Atropurpurea' and 'Laciniata'. The cultivar 'Fastigiata' did not respond significantly to either blanching or etiolation plus banding, perhaps because the buds of this plant broke nearly a week before an etiolation structure could be erected over the developing shoots.

Table 1. Rooting percent response of four *Fagus sylvatica* clones to blanching, and etiolation followed by banding.

Treatment	Cultivar			
Stockplant/ shoots	Species	'Atropurpurea'	'Laciniata'	'Fastigiata'
Light grown/ no band	13.9[z]a	2.5 a	18.0 a	27.5 a
Light grown/ blanched	20.0 a	0.0 a	12.5 a	26.1 a
Etiolated/ banded	64.3 b	25.0 b	84.6 b	44.0 a

[z] Means within cultivar separated by Duncan's LSD, p=0.05.

***Acer saccharum* cultivars:** The responses to etiolation and banding were compared among *A. saccharum* cultivars Arrowhead, Green Mountain, Legacy, and Seneca Chief, which were containerized and forced in a greenhouse during the winter of 1987

(Table 2). The two cultivars, 'Arrowhead' and 'Seneca Chief' broke bud about 2 weeks before the other cultivars and showed significant responses to etiolation though not the additional treatment of banding. The other cultivars, Green Mountain and Legacy, broke bud later and, as a result, were grown and propagated in a substantially warmer greenhouse environment, which may have affected their responses to etiolation and banding. Shoots of 'Green Mountain' showed a slight trend toward improved rooting of etiolated shoots. The rooting response of 'Legacy' shoots actually appeared to be inhibited by banding. All *A. saccharum* cuttings were allowed to root for 35 days.

***Syringa reticulata* cultivars:** Plants of *S. reticulata* were containerized and forced in a greenhouse during the winter of 1987. With the two cultivars, Ivory Silk and Summer Snow, we investigated the necessity for an application of rooting hormone at the time of sticking the cutting. Rooting responses were assessed at

Table 2. Rooting percent response of four *Acer saccharum* cultivars to blanching, etiolation, and etiolation followed by banding.

Treatment	Cultivar			
Stockplant/ shoots	'Arrowhead'	'Green Mountain'	'Legacy'	'Seneca Chief'
Light grown/ no band	0.0[z]a	22.8 a	42.0 a	28.1 a
Light grown/ blanched	—[y]	14.4 a	20.1 a	—
Etiolated/ no band	38.6 b	27.8 a	38.3 a	72.1 b
Etiolated/ banded	38.6 b	27.4 a	18.5 a	72.3 b

[z] Means within cultivar separated by Duncan's LSD, p=0.05.
[y] (—) this treatment not applied.

Table 3. Rooting percent response of *Syringa reticulata* 'Ivory Silk' to blanching, etiolation, and etiolation followed by banding; with or without a 4000 ppm IBA (50% EtOH) quick-dip at the time of sticking.

Treatment	Rooting time in bench (weeks)			
	2		4	
Stockplant/ shoots	No hormone	IBA quick dip	No hormone	IBA quick dip
Light grown/ no band	0.0[z]a	5.3 ab	22.3 a	40.0 ab
Light grown/ blanched	3.3 ab	43.8 c	81.7 d	86.7 d
Etiolated/ no band	0.0 a	10.0 b	57.4 bc	75.4 cd
Etiolated/ banded	6.7 ab	78.0 d	75.0 cd	88.0 d

[z] Means within rooting time separated by Duncan's LSD, p=0.05.

both 2 and 4 weeks to discern if the speed of rooting was affected by the etiolation or banding treatments.

Blanched cuttings of the cultivar, Ivory Snow, which had rooted for 2 weeks yielded significantly greater rooting percentages than the light-grown, unbanded control only when treated with IBA at sticking (Table 3). A clear synergism occurred between etiolation and banding.

After 4 weeks in the rooting bench, cuttings treated by blanching, or etiolation plus banding, rooted significantly better than the control, whether or not hormone had been applied at sticking. More than two times as many roots per rooted cutting were present in cuttings which had been blanched or etiolated and banded (data not shown). In no case did adding hormone at sticking significantly improve the rooting response. From this data it would appear that blanching alone, with no additional hormone treatment, can insure successful rooting of *S. reticulata* 'Ivory Silk'.

Cuttings of the cultivar, Summer Snow, allowed to root for 2 weeks also showed significant responses to blanching without significant increases in response to either etiolation or the application of IBA at sticking (Table 4). The same trends were evident for cuttings allowed to root for 4 weeks, the best rooting obtained from etiolated and banded shoots. Again, etiolated and banded cuttings produced twice as many roots per rooted cutting on the average (data not shown).

As opposed to the *A. saccharum* cultivars, shoots of *S. reticulata* responded best to banding, not etiolation. Thus, in this case, it might be advisable to retain only the blanching treatment, eliminating the need for prior etiolation. Furthermore, when working with *S. reticulata* it would be possible to omit the application of IBA at sticking. A necessary follow-up experiment to this would be one examining the use of hormone on the band, when it is applied to the

Table 4. Rooting percent response of *Syringa reticulata* 'Summer Snow' to blanching, etiolation, and etiolation followed by banding; with or without a 4000 ppm IBA (50% EtOH) quick-dip at the time of sticking.

Treatment	Rooting time in bench (weeks)			
	2		4	
Stockplant/ shoots	No hormone	IBA quick dip	No hormone	IBA quick dip
Light grown/ no band	4.0[z]a	4.4 a	36.0 a	70.0 bc
Light grown/ blanched	12.0 ab	34.0 bc	72.0 c	79.2 c
Etiolated/ no band	4.0 a	6.0 a	40.0 a	40.8 ab
Etiolated/ banded	22.0 abc	48.3 c	86.0 c	93.3 c

[z] Means within rooting time separated by Duncan's LSD, p=0.05.

developing shoot, to determine if the banding effect derives from the exclusion of light, the presence of IBA in close proximity to the developing stem, or both treatments.

Stewartia pseudocamellia: Ten stock plants of *S. pseudocamellia* were containerized and forced in a greenhouse during the winter of 1987, again to examine the need for hormone application at sticking. Cuttings of *Stewartia* rooted rapidly, usually within 2 weeks. Furthermore, we were able to obtain a tremendous number of cuttings from just a few stock plants (1000 cuttings from ten 72 cm plants). Therefore, in addition to the usual cutting "take" at 4 weeks we took cuttings at 8 weeks, to see if a "window of rooting" indeed existed for *Stewartia*, and if this might be affected by etiolation.

In contrast with the effect of hormone application on the rooting of *S. reticulata* shoots, cuttings of *Stewartia* showed significant increases in percentage rooting whenever hormone was applied at sticking (Table 5). After 4 weeks greening any light exclusion treatment had significantly improved rooting. Etiolation and blanching were equally effective in promoting the rooting of cuttings treated with IBA before sticking. Etiolation plus banding yielded 100% rooting within 2 weeks, a significant improvement over blanching alone. Etiolation plus banding also tripled the number of roots produced per rooted cutting on the average (approximately 18), while etiolation of any sort doubled the average length of the longest roots produced (data not shown).

The rooting of all *Stewartia* cuttings decreased after 8 weeks greening. The best rooting was sustained in cuttings which had been initially etiolated and then treated with IBA at sticking. Furthermore, cuttings from shoots which had been etiolated, banded, and treated with IBA still rooted at close to 100%. Again, the banding of etiolated shoots resulted in a trebling of root number (data not shown).

Table 5. Rooting percent response of *Stewartia pseudocamellia* to blanching, etiolation, and etiolation followed by banding; with or without a 4000 ppm IBA (50% EtOH) quick-dip at the time of sticking.

Treatment	Stockplant greening time after banding applied (weeks)			
	4		8	
Stockplant/ shoots	No hormone	IBA quick dip	No hormone	IBA quick dip
Light grown/ no band	4.0[z]a	68.0 d	0.0 a	23.8 bc
Light grown/ blanched	22.0 b	88.0 ef	18.2 bc	35.0 c
Etiolated/ no band	50.0 c	97.5 fg	14.7 b	85.7 d
Etiolated/ banded	76.0 de	100.0 g	8.6 ab	94.4 d

[z] Means within greening period separated by Duncan's LSD, p=0.05.

Clearly, having initially etiolated shoots resulted in nearly 100% rooting in cuttings of *S. pseudocamellia*, even as the rooting response of control cuttings decreased during the additional 4 week period of greening. Etiolation alone extended the "window of rooting". When hormone is applied to shoots which have been previously etiolated it would appear that the additional treatment of banding may be omitted.

CONCLUSIONS

From this work it appears that the successful rooting of *Fagus sylvatica*, *Acer saccharum*, and *Stewartia pseudocamellia* may be accomplished using shoots which have been etiolated in the first week of their development. It is intriguing that shoots initially grown in the dark to a length of only 5 cm and greened for 2 months will still root so much more easily than light-grown shoots. Etiolated shoots of *Stewartia* greened for 4 or 8 weeks were morphologically indistinguishable from initially light-grown shoots. This reminds us of the intriguing possibility that anatomic and physiologic changes are occurring.

Stewartia cuttings also benefitted from additional hormone at sticking while *S. reticulata* cuttings did not. Of the species tested in this study, only *S. reticulata* responded more to banding than to etiolation. This pattern has been noted in previous studies with *Carpinus betulus*, *Corylus americana* 'Rush', and *Syringa vulgaris* cultivars (6).

Repeatedly, we have observed increases in the rooting of shoots treated by etiolating or banding. This has allowed us to make rapid progress in our studies of cutting propagation. The work is exciting and much remains to be done. In the years to come we hope to answer, in our study of the changes occurring in those tissues that are destined to form roots, many of the important questions regarding light effects on the adventitious rooting of cuttings.

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VOICES FROM THE PAST

HARRISON L. FLINT

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For several years, I have had a growing feeling that we are ignoring our heritage in IPPS. We do a reasonably good job of remembering and honoring long-time colleagues and former colleagues, as it should be, but we do not do so well in remembering the skills and wisdom that they have contributed to us. When I hear a question addressed that was answered 20 years ago, and perhaps a few more times since, I sometimes wonder why the speaker is not aware of the earlier answer. The reason seems simple: we don't often enough read our Society's back publications.

When I told Kathy Freeland that I was considering saying something on the topic of "re-inventing the wheel," she was kind enough to send me a sampling of topics that some of you requested for this year's program. From her list I selected three plant genera about which people had asked for more information: *Daphne, Kalmia,* and *Sciadopitys.* Then I checked our Proceedings for the past 35 years to see what you and others have reported on propagation of these plants since our Society had its start. Some of this information I now pass on to you.

Daphne. Much of the information on *Daphne* in the IPPS Proceedings relates to *D. odora* and other evergreen species and comes from meetings of the Great Britain and Ireland (G.B.&I.) Region. My guess is that the person requesting more information was more interested in the deciduous daphnes that more of us in North America can grow, so I will emphasize them.

In 1953, Leslie Hancock in Ontario, Canada, reported variable rooting of *D. cneorum,* averaging 50 to 75% as compared with 100% for other *Daphne* species. A decade later (1964), Bruce Briggs reported success with *D. cneorum* 'Ruby Glow', using semi-hardwood cuttings (August to September in Washington state), in sharp sand, well drained. Cuttings from plants grown dry rooted better than ones from lush plants. G. P. Chandler reported at the G.B.&I. Regional Meeting in 1969, that stock plants of *D. cneorum* were better left in open ground than potted in the greenhouse for flushing of vigorous growth, as he had found worked well for *D.* × *burkwoodii.* He used semi-mature cuttings (late June or July in Dorset, England) in sand: peat moss (2:1, v/v), closely spaced to conserve moisture, and watered thoroughly at first and not again until they had rooted (6 to 8 weeks), but shaded on bright days meanwhile.

Propagators seem to agree that *D.* × *burkwoodii* 'Somerset' is one of the easiest daphnes to propagate by cuttings—perhaps one reason for its great popularity in the 1960's. At a discussion at the G.B.&I. Regional Meeting in 1979, there was little agreement as to whether soft or half-ripe cuttings root more easily, for any *Daphne* species.

Summarizing, the limited evidence presented thus far suggests two things. First, a propagator starting with cutting propagation of *Daphne* might try semi-mature cuttings from healthy but not overly vigorous stock plants, taken as early in summer as such wood is available, perhaps treating with a hormone of moderate strength (such as 0.3 to 0.8% IBA in talc) as a precaution rather than necessity, and using sharp sand for maximum aeration. Watering might well be held to a minimum after an initial soaking, assuming the cuttings will be shaded from direct sun.

Second, the need for more information seems clear, especially the need for careful experimentation with techniques that can be compared in different climatic regions.

Kalmia. Successful micropropagation of *K. latifolia,* first reported to this Society in 1980 by Gregory Lloyd and Brent McCown of the University of Wisconsin, created a stir of excitement and paved the way to commercial propagation of superior cultivars. The story up until then had been one of frustration and spotty success. Yet there were individuals who had been successfully propagating mountain laurel earlier. In 1963, and again in 1967, Bill Curtis told of the success of an Oregon neighbor who managed 75 to 80% rooting of white-flowering forms and 50% rooting of pink-flowering forms year after year, with bottom heat under a sand and peat rooting medium and no added hormone, starting in March.

Bruce Briggs in 1964 described *K. latifolia* 'Ostbo Red' (then called "Ostbo #5") as "difficult to root," but not impossible, when semi-hardwood cuttings were stuck in sand:peat (2:3, v/v) in a closed case. In 1966, Al Fordham reported success in rooting cuttings of one of the Dexter selections of *K. latifolia,* with best results using a solution of 1000 ppm each of IBA and NAA, as a quick dip. By 1977, he was able to report success in 30 rooting trials over a 10-year period, with at least 80% rooting in 23 of the 30 trials and at least 90% in 14 trials.

In 1967, Sid Waxman included *K. latifolia* in a study of cutting propagation under fluorescent light. At intensities of 160 to 180 ft-c he achieved 60% rooting of Richard Jayne's, clone #137, which he (Sid) described as "notoriously difficult to root." The general level of desperation at that time is illustrated by Brian Humphrey's answer to a question on cutting propagation of a *K. latifolia* clone at the 1968 G.B.&I. Regional Meeting. He said, "I have tried with disastrous results. It is better propagated by grafting . . . on *Kalmia* seedlings". Likewise, John E. Eichelser, at the 1972 Western Regional Meeting quoted a fellow propagator in the Pacific Northwest on 'Ostbo Red': "useless to try to root it as it has been tried and could not be done". John himself was more successful, obtaining about 50% rooting the patient way, taking cuttings monthly from June to January. January cuttings, following a few freezes, rooted 25 to 30% by late May. Clean callused cuttings re-stuck eventually doubled the final count.

In 1971, 1976, and 1981, Dick Jaynes gave progress reports on his *Kalmia* breeding work, also reviewing progress in propagation. He noted that there was widespread disagreement on timing of cutting propagation, with recommendations varying from March to June, July, and August to December. He also stressed the importance of age of stock plant. In one comparison, he found cuttings from 1-year seedlings rooted 89%, those from 2-year seedlings 33%, and from 3-year seedlings 21%, while cuttings from 1 to 3-year grafts and rooted cuttings rooted 60%. In another test with his clone #137, cuttings from 1-year rooted cuttings rooted 94%, from 8-year-old rooted cuttings, 31%, and from 15-year-old original plants, 30%. In 1981, he noted that great gains had been made, with more progress needed, and pointed out the dramatic change made by the current success in commercial tissue culture propagation of *K. latifolia*.

Now that tissue culture is the mode, is the research done before tissue culture just so much wasted effort? I don't think so. The understanding of rooting responses and juvenility that emerges from those results is already finding application in tissue culture, and may become even more important as problems continue to emerge in tissue culture that require understanding of the physiology of the whole plant for their solution.

Sciadopitys. This striking conifer is a good example of how a plant considered difficult to root sometimes can progress to the status of being commercially feasible through uncovering a few simple facts about its physiology. As early as 1960, Sid Waxman pointed out that readiness of *S. verticillata* to root well depends on it's having received enough chilling to break internal dormancy. Cuttings made in late winter rooted in high percentages. This was quickly confirmed by Bill Flemer III (1961), and Jerry Verkade (1963). Sid pointed out that *Sciadopitys* behaves just the opposite of *Taxus*, which is best rooted earlier so that dormancy holds back budbreak until after roots have formed.

In 1978, Sid showed evidence of large clonal differences in success of rooting, and hypothesized that large resin discharge from cuttings of certain clones, possibly blocking intake of water or oxygen, might account for clonal differences. Soaking cuttings in dilute solutions of IBA had invariably produced better rooting than quick-dip or powder treatments. Soaking of cuttings in water before application of IBA allowed resin exuding from cuttings to be washed into the soaking water. Rooting percentages were nearly twice as great for soaked cuttings as for unsoaked. In this way the persistence and ingenuity of one propagator, encouraged and assisted by others, has made cutting propagation of *Sciadopitys* commercially feasible.

AVAILABILITY OF INFORMATION

Looking into all this took a little time but it was not a difficult effort for me. Why? I have several advantages. First, I am old enough to have attended my first IPPS meeting in 1961, so I have all but the first 10 years of the Proceedings (and one missing later volume) in my personal library, along with our excellent 30 volume Index. I also have the advantage of a major university library at my fingertips (even though they are missing five volumes!). Many other members have equally easy access to the Proceedings. But by no means all.

Many of our members have been with us for only a few years, and so have been exposed to only a few meetings, and have received only a few volumes of Proceedings. Probably many do not have access to earlier back volumes of the Proceedings, not to mention the many additional contributions that have appeared in *The Plant Propagator* over the years.

There is no way new generations of plant propagators can enjoy the same personal associations that have infused us with enthusiasm. They will find their own inspiration. But there are things we all can do to avoid losing the wisdom of our senior associates as we eventually lose their physical presence. More things than I can think of, probably, but I do have a few suggestions.

First, let's be sure the writings of our members are preserved. We have done that reasonably well in our bound *Proceedings*, but what about the reports of original research that have appeared in *The Plant Propagator*?

Next, how can we make these writings more accessible? Our Purdue University libraries do not have a complete set of *The Plant Propagator* and I suspect many other libraries do not have, either. Even if one had access to all issues, a serious search for any specific information therein would be very time consuming. Shouldn't we be thinking seriously of preparing an index for *The Plant Propagator* similar to the one we already have for volumes 1–30 of the Proceedings, and/or reprints of original research reports from *The Plant Propagator* for distribution to members and libraries. What better time to consider such projects than now, at the end of the of *The Plant Propagator* in its original form?

Finally let us resolve, by reading those back publications that we can find, to listen to the voices from our past as we prepare to find new information. In so doing, we can learn from our predecessors as we pay them the greatest possible tribute: listening to their words.

ROOT PIECES AS A MEANS OF PROPAGATION

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Propagation by root pieces is not obsolete as long as it is economically viable. In spite of the many changes and developments in plant propagation during the last half century, the propagation by root pieces is still a practical and profitable method for certain types of plants.

Reasons for using this method of propagation include: less labor may be involved; the work load may be distributed to periods of reduced demand; less time and space in the propagating facilities, or even none, may be required; and lower crop rollover time may be necessary. For these and other lesser reasons, well managed nurseries still continue using piece root propagation for certain crops.

The source of the root materials is from the growing fields after the crops have been removed. Occasionally, small quantities are dug with a sharpened spade from growing plants in the nursery. All roots are dug in late October and November.

For root recovery until the 1950's, the empty fields were plowed to a shallow depth with a turn plow. This was followed with loosening and collecting with a spring-tooth harrow. This practice was discontinued with the introduction of the spring-trip, solid-shank cultivator. These shanks are equipped with long, narrow, bull-tongue type shovels. This is a one-tool-operation that does less damage to the roots. Depending on the type of roots, the type of soil, and the amount of soil moisture, from two to four passes with the cultivator are normally necessary. The roots are transported at frequent intervals to the propagating facility to avoid dehydration.

There are optional ways of handling the roots from this point. For root masses with many fibrous feeder roots, storage may be outdoors in recessed cold frames until early spring planting. For heavy, fleshy roots with little or no feeder roots, the direct sticking in pots and dormant storage in cool greenhouses during the winter season; then a period of active growing during the spring and early summer; followed by mid-summer planting in the field is an expedient method. There are slight variations on these methods which are of minor importance.

For several decades, one nursery I know has planted annually 4,000 to 7,000 root masses of *Forsythia* × *intermedia* cultivars with or without sprouts. The root masses were pruned to under 4 in. so as to pass through the planter shoe. Any root sprouts present were pruned to 4 to 6 in. These prepared root masses were healed-in using a perlite mulch in large deep nursery flats. This perlite was salvaged from the propagating bench medium after renewal. These flats were stored in recessed, unheated cold frames from November until field planting time in the spring. Two layers of roll lath shading covered the frames from November until mid-March. A single covering was retained from mid-March until planting time in April or May. If planted early, these forsythia made heavy two-to-three and, frequently, three-to-four feet landscape grade plants by October.

Additional deciduous shrubs still grown efficiently by this system are *Acanthopanax sieboldianus* [syn. *A. pentaphyllus*], *Symphoricarpos* × *chenaultii*, 'Hancock', *Hypericum calycinum*, and *Liriope* species. With the advent of indoor intermittent mist propagation and negative pressure ventilation, some deciduous shrubs grown from root pieces are converted to softwood summer cuttings. This conversion produces heavier, faster growing plants and reduces production time by one year. *Aronia, Clethra, Comptonia, Euonymus, Spiraea,* and *Viburnum* are grown by this changed method of propagation.

The second method of direct sticking in pots is employed for heavy, fleshy roots with little or no feeder roots. These fleshy roots are cut about 4 in. long. Carefully observe polarity until potted. Three-inch clay pots are used with a soil-peat-perlite mixture. These are plunged, pot to pot, in a salvaged perlite mulch. At least one in. or more of perlite is desirable under the pots. One-half to one in. of perlite mulch should be above the rim of the pot after settling by watering. These are carried moist, but not extremely wet, from December through February. A night temperature of 32 to 40°F is best during this period. With day temperatures of over 70°F the house should be ventilated. Starting in early March, feed monthly with a 20-20-20 soluble plant food. As the growing season warms up, carry a slightly higher moisture level in the mulch. Stabilizing of the moisture level by the capillary action between the perlite mulch and the potting soil stimulates and stabilizes the steady, rapid growth.

Plastic pots are a poor second choice. Do not use peat pots or light soilless mixtures. The use of any of these materials inhibits the capillary action and impedes rapid growth. If used, the plants will not have sufficient size and vigor for mid-summer planting in the fields. The use of light soilless mixtures is hazardous for summer planting unless irrigation can be supplied every 5 to 7 days. Such is not the case with a soil-peat-perlite mixture.

This second method is highly suitable for cultivars of lilac (*Syringa vulgaris*) and flowering quince (*Chaenomeles* spp.). Two-year lilacs, grown from root cuttings, are equivalent to four-year-old plants propagated by softwood cuttings. Lilacs grown from root cuttings are nearly 100% successful in the propagating beds as well as in the growing fields. Success with softwood cuttings of lilac are rarely reported. Favorable performance may be expected from the flowering quince. Saleable plants are more shapely and fully branched, and are produced more quickly than softwood cutting-grown plants.

The development of piece root cutting-grown lilacs exceeds that of lilacs grafted on *Syringa, Ligustrum,* or *Fraxinus* understocks. These root produced plants are not associated with the problems of grafted lilac. These problems include short useful life expectancy, understock incompatibility, constant sprouting of the understock, and the inability of grafted lilac to regenerate following an attack of lilac borers.

Field soil should be prepared in advance of the late July and August planting time. Delay planting until there is a heavy rain of over 1 in. preferably over 1½ in. As soon as the rain has settled, and mud does not clog the planter shoe, set the plants in the field. Two to three days after planting, overspray with Surflan pre-emergent weed killer and cultivate in lightly. This will be effective for the remainder of the growing season. For the balance of the season, the plants will make a relatively small amount of top growth, but an abundance of root growth. The following spring, these will make an extra-early start. With seasonal rainfalls during the summer months, there will be substantial secondary growth.

Prior to propagation of softwood cuttings under intermittent mist, some small flowering trees were grown by root cuttings rather than by grafting. Some were by direct sticking in pots, while others were in propagating beds to be potted after rooting. This has, for the most part, been curtailed due to slow production growth and to branching trees that are difficult to structure. These include *Amelanchier, Cotinus, Malus, Prunus,* and *Pyrus.*

Propagation by root pieces is not limited to woody plants as may be assumed from all that has been stated so far. Many herbaceous perennial plants may be propagated by the methods outlined. *Papaver* may be propagated during their summer dormancy by fleshy piece roots directly potted in a soil-peat-perlite mixture or stuck in the propagating bed medium for rooting and later potting. Be sure to stick vertically and observe polarity.

Many fleshy rooted herbaceous perennials can be propagated by 1 in. pieces during their winter dormancy. In November or early December, nursery flats are filled with a soil-peat-perlite mix, and the root pieces broadcast on the surface, covered with about ¾ in. deep perlite. These are carried in a cool greenhouse during the winter season. As the spring season approaches, new feeder roots penetrate into the soil and foliage develops. Individual potting is usually made in late April and during May. Grown in this manner are *Anemone × hybrida, Dicentra eximia, D. spectabilis, Phlox paniculata,* and *Stokesia laevis.*

Growing from piece roots is historically one of our older methods of vegetative propagation. Old is often interpreted as being obsolete. Obsolete is defined as "of a discarded or outmoded type; out of date." It is freely admitted that some root piece propagation has been replaced with more modern methods. It is doubtful that any of those assembled here today will see tissue culture propagation substituted for the rapid and vigorous piece root propagation of hybrid lilacs.

Please note these observations have been made for the U.S. mid-Atlantic states.

EASTERN REGION QUESTION BOX

The Question Box Session was convened on Thursday at 4:45 p.m. and again on Friday at 10:40 a.m. Both sessions were combined and presented here as one. Bruce Briggs and Ralph Shugert served as moderators.

MODERATOR SHUGERT: Question for Robert Gouveia. How often and how do you change media in your sunken beds? It seems that it would be quite difficult to do. From our experience, sunken beds like yours are great for ground heat effects but pose some problems when either treating the medium or changing it.

ROBERT GOUVEIA: It is pure sand and we change it every two years. We just wheelbarrow it in and out. We are thinking of adding perlite to the medium. We do not treat it chemically but simply remove the top 1 to 2 in. of sand at the end of the first season.

MODERATOR SHUGERT: Question for Gary Koller. Why should the horticulture industry concentrate on providing dwarf and slow growing cultivars to customers who typically prefer quick establishment and immediate impact. Homeowner "life expectancy" dictates results in 3 to 5 years. How can your "dreamscapes" be provided at a cost which is not prohibitive?

GARY KOLLER: Most homeowners do want quick establishing plants, however, I do see a growing pool of landscape designers and architects who realize that when they put in these rapidly growing plants the quality of their design deteriorates rapidly because they can not afford to provide the horticultural maintenance or find people to provide that maintenance. Therefore they are thinking of transferring some of those dollars from maintenance costs into plant costs and put less into maintenance over the long term. These landscape architects are trying to create effects that last over time, and are the people who are looking for these new plants. It will take some education on our part to convince the homeowners to transfer some maintenance costs to plant costs.

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MODERATOR SHUGERT: Question for Chris Rogers. Your savings in costs seem to result more from direct sticking vs. bench cuttings than from use of fog. Any comments?

CHRIS ROGERS: That is true, however you obtain better rooting percentages with fog.

MODERATOR BRIGGS: When is the best time to root *Euonymus bungeana* and *E. europaea* stem cuttings? Can softwoods or semihardwoods be used? In Dirr and Heuser's new book on propagation, examples cite August and November. Why so late?

VOICE: Most any time during the summer time will work. Use semi-hardwood cutting material, 0.8% IBA, and mist. Keep them on the dry side. They will take a little time to root and you can pot them up in the fall.

MODERATOR BRIGGS: On Tuesday I heard about container production in which more than one woody cutting was placed in a container. What happens after this multiple plant is placed in its final site? Two or three plants have to live and compete in the space which should be occupied by one.

BRUCE BRIGGS: On the West Coast highway departments sometimes are concerned if you are putting in seedlings because they might have different growth rates and not all look alike.

ROBERT GOUVEIA: We are just in the experimental stage but more than one cutting is just insurance that you will have something in that container as a backup. If you have three cuttings, which I consider the best, you get a more uniform plant in a container and that container is saleable sooner.

BRUCE BRIGGS: We use multiple cuttings a lot. We put three cuttings because we get a fuller container and it finishes faster. However, it costs more money because you have to take three cuttings.

MODERATOR SHUGERT: Should propagators remove the flower buds from small-leaf rhododendron cuttings prior to sticking?

JIM CROSS: If you are referring to the very dwarf types, such as *R. impeditum*, than you will get damage from disbudding. With the intermediate types, such as the *R. carolinianum* types, we have found better results with disbudded cuttings, especially with the more difficult-to-root forms. The cuttings will also flower and this will be a source of litter to clean and to cause potential diseases.

MODERATOR SHUGERT: Please discuss plant patents. Can I propagate a patented plant and voluntarily reimburse the patent holder? Can I propagate and sell *Ilex verticillata* 'Winter Red' as just *I. verticillata* and not worry about the patent? What happens if I'm caught infringing on a patent?

RALPH SHUGERT: The U.S. is the only country with a plant patent mandated by law. The patent lasts 17 years.

BILL FLEMER: No you can not propagate a patented plant and voluntarily reimburse the patent holder. You can apply to the patent holder for a license to propagate. If you are caught infringing on a patent, you can be sued for triple damages which can amount to a lot of money. I know of one case that settled for $100,000 and another over $300,000.

ROBERT ADAMS: Both the plant and name I think are patented and therefore it would not be legal to propagate *I. verticillata* 'Winter Red' as *I. verticillata*.

MODERATOR SHUGERT: Has anyone experienced problems with the use of fresh cedar shingletow for the storage of bareroot cuttings? Should it be aged before use?

BILL FLEMER: We use it fresh in storage and feel that it has fungistatic properties. It is not good for propagation because the same compounds that give it fungistatic properties inhibit rooting and root growth. It should not be aged.

MODERATOR BRIGGS: Has anyone experienced inhibition of rooting when using Banrot as a propagation medium drench? Especially in plug production in soilless media?

VOICE: We have used it as a drench with *Vinca minor* with good results. With the idea that if a little is good a lot is better, a couple of years ago we incorporated the granular form in our peat:perlite:bark mix and also did a drench. I have not yet decided if that cost me 35 or 40,000 dollars. We got very little rooting.

MARK RICHEY: I have used it on many different softwoods and taxus cuttings and found that as long as the medium is well aerated there was no problem. A poor draining or aerated medium showed some rooting inhibition.

BRUCE BRIGGS: When trying something new try it on a small scale first.

MODERATOR BRIGGS: Can methyl bromide be used to sterilize/sanitize a propagating house? Will it damage plastic mist lines or poly covers?

BRUCE BRIGGS: Don't do it because you would be opening up many problems.

PETER ORUM: We have used formaldehyde (1:100 ratio) and simply spray the plastic house. Use a mask and seal the house after spraying for a few days.

VOICE: One comment on the use of formaldehyde. It is a known carcinogen.

MODERATOR BRIGGS: What can be done to control algae in a mist house?

TOM KIMBLE: We obtained good results with a bromide product, I believe it is called Aqua Brome and is used in swimming pools.

BRUCE BRIGGS: We have used the same product and find it to work. We were looking at it for control of liverworts and mosses. It looks good in the range of 2 to 3 ppm. We tried chlorine, since there is no residue.

TOM McCLOUD: We have used chlorine too, but it has no residual action. I noticed that Ball Seed Co. was using rock salt in the stone areas under the benches to control weeds and fungus gnats.

MODERATOR BRIGGS: How do you treat *Hamamelis virginiana* seed so that it germinates the first spring? I've tried 60 days warm, then 120 days cold, and have gotten 5% germination the first spring.

(EDITOR'S NOTE: The key is breaking the leather-hard seed coat down. Work in England (IPPS Proc. 34:334–342) showed that 2 months warm/2 months cold/2 months warm/4 months cold produced 88% germination).

MODERATOR BRIGGS: Is there any great difference between *Pinus densiflora* 'Oculis Draconis' and *P. thunbergiana* 'Oculis Draconis'? Which does better in the midwest.

HARRISON FLINT: Yes, they are two different species. *P. thunbergiana* should be hardier.

MODERATOR BRIGGS: What are the chilling requirements for seed of *Trillium grandiflorum* and *T. sessile*?

(EDITOR'S NOTE: Seeds of *T. grandiflorum* and probably other species are noted for their "double dormancy". Two cold periods are required. The first removes a block to root growth. The first cold period is followed by a warm period for root growth that is followed by a second cold period which removes the block to shoot growth. The need for a second cold period may not be needed if the seeds are sown fresh, without being allowed to dry.)

THURSDAY EVENING, DECEMBER 10, 1987

The thirty-seventh annual banquet was held in the Grand Ballroom of the Sheraton International Hotel at O'Hare, Chicago, Illinois.

On behalf of the Society—Eastern Region, the annual Research Award was presented to Timothy J. Smalley and Dr. Michael Dirr, Department of Horticulture, University of Georgia, Athens, Georgia. The title of their study was "Regulation of Photosynthesis During Rooting of *Acer rubrum* 'Red Sunset'."

EASTERN REGION AWARD OF MERIT

Leonard Savella made the following Award of Merit presentation:

The Award of Merit is the highest award the Eastern Region of the I.P.P.S. can bestow. To receive this award is indeed a great honor.

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HARRISON FLINT: Yes, they are two different species. *P. thunbergiana* should be hardier.

MODERATOR BRIGGS: What are the chilling requirements for seed of *Trillium grandiflorum* and *T. sessile*?

(EDITOR'S NOTE: Seeds of *T. grandiflorum* and probably other species are noted for their "double dormancy". Two cold periods are required. The first removes a block to root growth. The first cold period is followed by a warm period for root growth that is followed by a second cold period which removes the block to shoot growth. The need for a second cold period may not be needed if the seeds are sown fresh, without being allowed to dry.)

THURSDAY EVENING, DECEMBER 10, 1987

The thirty-seventh annual banquet was held in the Grand Ballroom of the Sheraton International Hotel at O'Hare, Chicago, Illinois.

On behalf of the Society—Eastern Region, the annual Research Award was presented to Timothy J. Smalley and Dr. Michael Dirr, Department of Horticulture, University of Georgia, Athens, Georgia. The title of their study was "Regulation of Photosynthesis During Rooting of *Acer rubrum* 'Red Sunset'."

EASTERN REGION AWARD OF MERIT

Leonard Savella made the following Award of Merit presentation:

The Award of Merit is the highest award the Eastern Region of the I.P.P.S. can bestow. To receive this award is indeed a great honor.

The recipient of this year's award is truly deserving. He started his nursery career at the young age of 6 years. Between 6 and 12 years of age he worked on an estate owned by a Miss Case who also allowed the recipient's parents, Peter and Anna, to grow rootstocks and have cows and chickens on the farm. Peter and Anna Olga Puren were childhood sweethearts in Latvia and Russia. They emigrated to America where they married and had two children—the recipient, and a daughter, Laura.

The recipient's job as a young boy was to maintain the peony and wildflower gardens of the estate, which are presently combined into the perennial display area at the Arnold Arboretum in Weston, Mass.

His other duties, along with his sister Laura, were to deliver door to door through the neighborhood the milk and eggs that the cows and chickens produced. His parents, through hard work managed to buy a small parcel of land on which they grew fruit trees and ornamentals. The recipient, working with his father, eventually increased their acreage and business ten-fold.

Our recipient attended local schools in Massachusetts and in 1933 went to Cornell University where he enrolled in the College of Agriculture. He graduated in 1938 with a Bachelor's degree in Landscape Architecture. He was a miler on the track team that traveled to England in 1938 to compete against the combined teams of Oxford and Cambridge Universities. He stayed on after the races to bicycle through England, Holland, Germany, and France, visiting nurseries that he had heard his Dad talk about so often.

In 1940 the recipient married his sweetheart, Wally Bralit. The new bride soon started working in the nursery office. They had two children, Wayne, born in 1942, and Roger born in 1944.

In the 1940's, along with his nursery business, our recipient was tree warden and moth inspector, as well as cemetery commissioner for the town of Weston, Massachusetts. Later, after moving to Hopkinton he was a member of the finance committee and then served for ten successive years as the Chairman of the City Planning Board from 1954 to 1964.

Our recipient was also president of the New England Nurserymen's Association in 1943, president of the Massachusetts Nurserymen's Association in 1952, a founder and first president of the Massachusetts Chapter of the American Rhododendron Society in 1970. He has been a member of the International Plant Propagator's Society since 1964.

His many presentations in the Society's programs have been most informative and educational, and will be of great help to young nurserymen and horticulturist for generations to come. He has left his mark. He was a great friend to all of us. He was a man who did not seek praise or recognition because he felt that what he did was what anybody would do. A man who possessed a talent and knowledge of plant propagation, hybridizing, and horticulture that very few will attain and yet among his peers he would be humble.

Here are some of the awards and honors bestowed on him that few of us knew about because he never talked about them or wanted a pat on the back. In 1967 he was awarded the Jackson Dawson Gold Medal of the Massachusetts Horticultural Society for his accomplishments in plant breeding and propagation. In 1974 he received the highest award, the Bronze Medal, given by the Massachusetts Chapter of the American Rhododendron Society. In 1978 he received the American Horticultural Society's Citation and Gold Medal for his outstanding contributions to commercial horticulture. In 1980 he was awarded the American Rhododendron Society's Gold Medal, and the Evelyn Mooney Award for Creative Horticultural Achievement by the National Council of State Garden Clubs.

It was in 1940 that he crossbred two rhododendrons to get the now famous 'P.J.M.' rhododendron which he named after his dad. This was just the beginning of a whole list of new rhododendrons and kalmias that he introduced to the plant world. His nursery now consists of over 1000 acres. A nursery that, in my opinion has the greatest selection of plant material in America. His nursery catalog is called the nursery bible because of the great selection of annuals, herbaceous and woody perennials. It is used extensively by New England nurserymen to learn the correct spelling and botanical names of plants.

YES, our recipient has left his mark.

The recipient of the I.P.P.S. Eastern Region Award of Merit this year is the late Edmund V. Mezitt. I am deeply sorrowed that our recipient is not with us today for he passed away in September, 1986.

I would like to present this award to his wife, Mrs. Edmund Mezitt, so that it can be displayed with his many other awards.

Sincerely,

Leonard Savella, Chairperson
Larry Carville
John McGuire
Gus Mehlquist
Joerg Leiss
Richard Zimmerman
James Cross
Leonard Stoltz

Friday Morning, December 11, 1987

The morning session was convened at 8:00 a.m. with Clayton Fuller serving as moderator.

PROPAGATION AND PRODUCTION METHODS FOR SOUTH JERSEY

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INTRODUCTION

South Jersey is in the center of the Bos-Wash megalopolis, and for the purpose of this discussion, includes approximately the southern 50 miles of New Jersey. The nursery industry is mostly located in a North-South strip in the center of the state. The production area is located in the center of the USDA Zone 7, which results in a climate similar to that of central to western North Carolina. On a calendar year basis, the season starts with propagation in January, and concludes in late December with the last digging of field stock.

Soils in the area are relatively light and well drained. The soil types in the area establish a critical need for irrigation in order to effectively produce nursery stock. Fortunately, the southern part of New Jersey sits upon the Cohansey aquifer. The aquifer water comes out of the Pine Barrens of New Jersey, which is a protected area, and results in one of the largest aquifers on the East Coast. Water in Cumberland County is generally found approximately 15 to 60 ft below the surface of the ground, with pumping rates in excess of 2000 gpm not uncommon for 12 in. wells. The importance of water can be demonstrated by considering the monthly electric bill for the very dry summer of 1987. One grower's electric bill for the operation of pumps exceeded $5000 for three consecutive months.

NURSERY INDUSTRY

The production of deciduous and evergreen shrubs, small shade trees, and a small but growing industry specializing in large specimen trees fills our niche for field stock production. Container production centers on those plants which will not ship well across the country such as evergreen shrubs, and specialty plant material. The propagation component of nursery production consists of seed propagation of shade trees, deciduous shrubs, and other specialty material, as well as cutting propagation of deciduous and evergreen shrubs, herbaceous perennials, and some trees. A small grafting industry remains in the area.

The value of the nursery industry in South Jersey is about $90 million, and it is mostly wholesale with a growing re-wholesaling portion. Over the last 6 or 8 years container stock has been the most rapid growth area for the nursery industry in South Jersey, with a value of approximately $60 million. Presently, there are approximately 1500 to 2000 acres of field stock in production with about 3000 additional acres having been purchased for the production of field stock in 1986 and 87. Shipment is mostly within a radius of 250 miles; a limited amount is shipped nationally and internationally.

I have become heavily involved in industry expansion. I receive calls averaging two per week from individuals interested in starting new operations. Most of those interested have no background. From my estimates, about 20% should succeed in the business. Expansion of existing operations ranges from 5 to 30%/year depending on the operation. The rate of expansion is highly dependent of the potential level of management.

PROPAGATION

Most commercial propagation in South Jersey falls into three classes: field seeding, cuttings, and grafting. Both the field seeding and the grafting are conducted using traditional techniques. Propagation by cuttings has benefited from advances in greenhouse engineering. While Professor William Roberts of Rutgers University conducted much of the early research into the application of heated floors for general greenhouse production, nurserymen have only recently adapted the technology to the industry. Nurserymen from the South Jersey area are presently using heated floors made of solid concrete in the propagation of nursery liners. They incorporate the double header return system and also make use of polybutylene tubing to conduct the flow of water.

Nursery liner stock produced using the floor heating system has resulted in a reduced production cycle, since the liner is larger when potted into the production container. Some azalea liners have up to a 6 in. crown size upon potting, and there is a like response for most plants produced on such a floor.

Early in the development cycle, growers used floor heat as the total source of the heat for the propagation houses. While liners overwintered and grew well, some liners entered a type of dormancy when potted and placed in the production houses in the spring. Presently, growers are using a system where the heated floors are allowed to drop to the vicinity of 40°F for a period of 45 to 60 days from mid-December to mid-February in an effort to overcome the dormancy problem. Energy conservation blankets of several types are now being used on an experimental basis in an effort to overwinter liners with less energy input.

Another area which has been seriously looked into has been that of misting and mist controlling. In addition to the traditional wire deflector nozzles, growers have used a spinner sprinkler imported from Israel, a large droplet fog system from Virginia, and a moderately high pressure true fog system engineered by area growers. All systems have benefits and drawbacks, and many growers are incorporating multiple systems depending on the crop produced. Controllers include a timer, a mechanical leaf, and a carbon-rod evaporation controller. Again, there is no definitive benefit of one system over another. It does appear that the traditional time-clock is being slowly replaced by more accurate clocks or evaporation systems. Most growers feel there remains the need for a better misting controller.

PRODUCTION

Labor management has been an area for increased concern in South Jersey. It has become increasingly difficult to get any type of labor for the industry. Both management level and laborer level personnel are in high demand. Employers are working intensively to make the work environment more desirable for their employees. In the development of this process, nurserymen have noted that personnel respond not only to reductions in the physical side of labor, but also to changes which make the working environment more desirable. The positive attitude of employees is a major factor in the success of labor management and the business.

While much of the innovation in technology has been directed toward the container industry, field operations have also benefited. A number of types of labor saving equipment has been integrated into area nursery operations. Some of those include the use and/or development of: big gun irrigation systems, potting machines, line mixers, skid steer loaders, loading docks, and conveyors. Also, growers have updated greenhouses to give more comfortable working conditions, to conserve energy, and to allow for a greater percentage of land coverage. The use of soil conservation practices including land shaping and ditching for water control, and the incorporation of new methods of applying pesticides more safely has also aided in benefits to worker interest and morale.

With the attitude that "quality sells", growers have instituted several methods of increasing quality through production practices. Post-production nutrition has become an area of increasing concern. Since growers are increasingly making use of name recognition in the marketing of stock, there is the need for the stock to look good not only at the time of delivery, but also for the period necessary for sales of that item in the garden center or other sales location. Fertilization to the very end of the production cycle or the use of granular or slow-release fertilizers prior to shipment have developed as options.

Winter watering has increased, with most growers watering container nursery stock at least once a week on the average during the winter. The rule of thumb most growers are now using is that of "if the root ball is unfrozen, water". Stock lost due to all factors in the winter has dropped into the 0 to 2% range.

Passive forcing is the technique of using sunlight to heat closed overwintering houses which results in rapidly increased growth of slightly undersized stock and/or enhanced the color of certain stock prior to sale. This process was developed in the area and is now being incorporated into the production programs of a number of area nurseries on specific types of stock.

NURSERY MANAGEMENT

Management and the management component of marketing are the keys to the most successful of area nursery businesses. It is well recognized that quality of produced stock allows growers to survive during periods of reduced sales and/or recession. In fact, the only parts of the market where we usually have problems are those where a "national" market exists. These "national" markets periodically over-supply our local markets with a low-cost product. In order to partially counter these periodic episodes of "dumping", growers are attempting to more effectively meet the needs of their clientele, and help establish a more personal relationship.

Analysis of production management programs for nurseries has indicated that profits to a large extent depend on the rate of turnover for the crop. As a consequence, most production is geared toward a one to two year crop. Since much of the cost of production is dependent on overhead costs, figures have been developed to determine the overhead cost per square foot of production area. Presently, growers are looking at the potential for the use of larger container production houses, thereby increasing the percentage of land used for production, in order to bring down the overhead costs.

With the periodic influx of excess nursery stock from other parts of the country, growers look upon expansion of their own businesses carefully. While there is an increase in production from year to year, growers base this increase on unfilled orders plus a percentage of production, also considering the business climate. There is little speculative expansion, resulting in a relatively stable local industry.

Computerization of nursery businesses has played a major role in all phases of business management. While there is considerable time spent in the entry of data, the options available for output and manipulation of information are well worth the investment of time. Computers are presently being used for billing, payroll, inventory, and orders. Output of information entered in addition to that of business analysis includes sheets for pulling orders which list the location of all plants to be pulled and a location for consolidating the orders. Fall grading of nursery stock with identification of grades by the use of colored plastic strips or ribbons is necessary for the rapid pulling of orders in the spring.

Education is another area which has stimulated quality growth of the industry in South Jersey. Traditional attendance at meetings of management and other higher level nursery personnel has expanded to include field workers. Applied research is being conducted not only by or in conjunction with Rutgers Cooperative Extension and Rutgers University, but also by growers themselves. Close interaction with Rutgers Cooperative Extension in problem solving has always been a strength of the industry, and will continue to be. In addition to the traditional forms of education or expanded forms, is the involvement of nursery personnel in educational trips. Presently, approximately 80% of the nurseries send individuals to various parts of the country and the world at least once a year looking for new ideas and new technology.

CRITICAL AREAS

South Jersey offers many benefits to the grower with respect to location, climate, infrastructure, and the number of progressive growers. Coupled with these benefits are also concerns. With the construction of an interstate highway into the area to be completed in the fall of 1988, and the existing proximity to Atlantic City, there has been a tripling of land prices in the last 18 months. New purchases of land in the area indicate that South Jersey is becoming a "bedroom community" for Atlantic City and Philadelphia. It appears that we will be feeling the effect of real population pressure in the near future.

In addition to the direct population pressure are the pressures of finding employees since other business is moving to the area as well. Pay, while being high, is not the issue. Hard work is. People are not willing to spend the time or energy associated with agricultural production when they can earn a similar salary elsewhere with less effort expended. Migrant labor, and the associated regulation, has also created additional concerns. Presently, we cannot find labor in the nursery business, either skilled or unskilled.

Pesticide use is of concern with the increasing urbanization of South Jersey. Regulations in New Jersey are among the most stringent in the United States which places us at a competitive disadvantage when compared to states with less stringent regulations. Aerial application of pesticides is decreasing as the result of regulation, as is the use of mist blowers in many locations. Liability problems may be the final blow in an individual's effort to remain in business.

Water quality, quantity, and runoff have recently become an issue of national importance. Even though South Jersey sits upon one of the largest aquifers on the East Coast, ground water is limited. We are in the midst of industry expansion and homeowners in the area, and there are projections of water crises in the future. There are also no options for reservoirs because of soil type problems, and there are no major rivers from which water can be taken in the South Jersey area. In an effort to maintain water quantity and quality, growers are now looking at options and alternatives for water conservation. Possibilities include the collection and recycling of water, with the monitoring of water quality already being conducted. There is also concern for terminal users of nursery production, the landscaper and homeowners, and their possible loss of the rights to use water during establishment of plants in the landscape.

OPPORTUNITIES

Where there are problems, there are also opportunities. The South Jersey nursery industry has been expanding rapidly for the last 6 to 8 years. The market is within an easy day of travel time, and will continue to expand in the foreseeable future. We have a very large proportion of progressive, results-oriented producers in the area, and an expanding market based on consumer demand. Growers also accept change as necessary for survival and expansion of their businesses. As a result, I see the South Jersey nursery industry as being a major factor in the innovative future of the nursery industry.

LEAF-BUD OR SIDE-GRAFT NURSE GRAFTS FOR DIFFICULT-TO-ROOT RHODODENDRON CULTIVARS[1]

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Abstract. The leaf-bud and side-graft methods were compared as methods for propagating rhododendron cultivars on unrooted nurse rootstocks in outdoor mist-beds in summer. No significant differences in grafting percentage were found between the methods nor did either method show inhibitory effects of scions on rooting of nurse rootstocks. Both methods produced plants within 10 weeks.

INTRODUCTION

The practice of placing a scion on an unrooted cutting, then rooting the cutting under intermittent mist while the graft union heals is not new. It was reported to this Society many years ago (1,5). Leach reported grafting difficult to root rhododendron cultivars in early summer on greenwood (3). He found early July or late June to be the best times. More recently Howard (2) demonstrated the modified chip bud method to propagate fruit trees and shade trees. The method was reported to be more successful than the conventional 'T'' bud.

It was decided to try the modified chip bud method on rhododendron, using a leafbud in early summer. The method was compared to conventional side graft and both were done on unrooted cuttings of R. × 'Cunninghams White'. Since Lee, et al. (4) reported a retarding influence of difficult-to-root scions on easy-to-root cuttings where they were used as stock plant cuttings, rootball diameter of stock cuttings was measured.

The potential advantage of using a leaf-bud scion on an unrooted rootstock is that one could propagate budwood of a new cultivar when it was in bloom. The new plants would be available within a few months. It is often difficult to relocate a plant after the flowers have fallen and one cannot be sure the correct plant has been propagated for several years. It is also not always possible to propagate a new cultivar by micropropagation until specific formulae are determined.

PROCEDURE

Unrooted cuttings of *Rhododendron* 'Cunningham's White' were used as rootstocks. All cuttings were 4 in. (10 cm) long and had five leaves which were reduced by half. Cuttings were wounded on

[1] Approved by the Director of the Rhode Island Agricultural Experiment Station, contribution no. 2399. Research was supported in part by funds from the Hatch Act.

[2] Research Associate

[3] Laboratory Aide

two sides and treated with a 5 sec dip in an IBA/NAA solution (1% 0.5%, respectively) diluted to 1 part to 3 parts of water. Scions were either a leaf and bud inserted at the point opposite the lowest leaf on the cutting by the modified chip bud method as described by Howard (2), or a standard side graft also placed opposite the lowest node on the stock plant. In both cases leaves of scions were not cut. All scions were wrapped with waxed grafting string. Cuttings and scions were identified by marking one leaf with a sample number using indelible ink. All treatments were replicated three times with five samples per replicate. The control treatment consisted of ungrafted cuttings. Cultivars compared were 'Dr. H. C. Dresselhuys,' 'Goldsworth Yellow,' and 'English Roseum'. All cuttings were placed in an outdoor ground bed in a medium of sphagnum peatmoss and medium grade vermiculite (1:1, v/v). Mist was applied at 6 sec/6 min and bottom heat was maintained at a minimum of 65°F. The bed was shaded with saran to provide 51% shade. All grafts and ungrafted cuttings were harvested after 10 weeks and average rootball diameter was measured. At this time foliage of the nurse stock was removed to force the grafts to grow. The plants were then placed in flats (11 cm deep) and placed in a heated greenhouse at minimum temperatures of 65°F. After 4 weeks the percent of successful budded plants or grafted plants was recorded and correlated to rootball development.

RESULTS

Percentages of budded and grafted plants were 46% for the leafbud and 42% for the side graft. There was no significant difference in percentage takes between the two methods. There appeared to be no difference in average rootball diameter between ungrafted cuttings and those with leaf-bud grafts but there does appear to be larger rootballs on plants with side grafts. This can be explained by increased leaf area on those plants due to the addition on the leafy scion. There was no evidence of retarding effects of scions of difficult to root cultivars of 'Dr. H. C. Dresselhuys' or 'Goldsworth Yellow' but there does appear to be a slight stimulus from scions of 'English Roseum'. It is assumed that an experienced propagator would get a higher percentage of takes than were obtained here since the personnel doing the work had limited experience in grafting.

The method can be used by anyone with limited skill in grafting. There appears to be no retarding effect of scion or leafbud on rooting and obviously if sufficient scion wood is available larger plants can be obtained using the side graft method, but if a new cultivar is desired, the modified chip bud on a nurse cutting could be used to obtain it in a short time.

Table 1. Average diameter of nurse root graft rootball of leafbud or side graft after 10 weeks.

Rhododendron cultivar	Type of Graft[1]		
	Leaf-bud	Side	Rooted cutting 'Cunningham's White'
Goldsworth Yellow	6.2 cm	6.9 cm	5.3 cm
Dr. H. C. Dresselhuys	6.8	7.6	5.3
English Roseum	5.5	9.7	5.3

[1] Rootstock—R. 'Cunningham's White'

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FIELD PERFORMANCE OF *IN VITRO* PROPAGATED BLUEBERRIES

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Abstract. 'Northblue' half-high hybrid blueberries were propagated *in vitro* and plants were planted in three locations in extensive field plantations for comparison with cutting-propagated plants. Beginning in the second year following transplanting, yields were significantly higher for the *in vitro* propagated plants for the next three years. Yield increases were attributed to a greater number of basal branches, and a larger number of flower buds. There were no differences in fruit size or quality.

REVIEW OF LITERATURE

Several researchers have reported methodologies for propagating various types of blueberries *in vitro* (2, 7, 11) We wished to establish potential commercial plantings of the half-high, relatively winter hardy blueberry types developed in the breeding programs initiated by Cecil Stushnoff and continued by James Luby (8). It was deemed appropriate to develop *in vitro* propagation schemes for propagation of the relatively difficult-to-propagate types resulting from these breeding programs. We were successful in developing such propagation systems (2, 3, 5). The logical next question was, do these *in vitro* propagated plants perform in a fashion equivalent to conventionally propagated blueberries? Therefore, field trials were established to ascertain the field performance potential of *in vitro* propagated 'Northblue' blueberry plants.

MATERIALS AND METHODS

In the winter of 1982, plants were propagated by cuttings and by *in vitro* methods, and then grown in greenhouses at the University of Minnesota. They were subsequently stored over winter in appropriate cold storage facilities and planted for comparison into three Minnesota field locations: Grand Rapids, Becker, and St. Paul. Details of propagation methodology, storage conditions and site characteristics for the field plantings can be found in previous publications (3, 4, 6). Measurements were made of number and length of basal branches, number and length of lateral branches, flower buds per branch, total number of flower buds, fruit yield in grams per plant, and fruit weight in grams per berry.

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[2] Former graduate students, University of Minnesota

[3] Department of Horticulture, University of Minnesota, Grand Rapids, Minnesota

RESULTS AND DISCUSSION

Yields were significantly higher for the *in vitro*-propagated plants in each harvest year following establishment (Figure 1). Similarly, differences in fruit yield and growth habit have been reported for strawberries (1, 9) and blackberries (10). The increased yield in blueberry was related primarily to the increased number of flower buds on the *in vitro*-propagated plants which was correlated with a greater number of basal branches. Figures 2a and 2b illustrate the difference in growth habit between plants propagated by the two methods. It was also noted that the *in vitro* propagated plants suffered less winter injury, possibly because of the ability of the more basal branching growth habit to hold snow and thus insulate the plants against the cold.

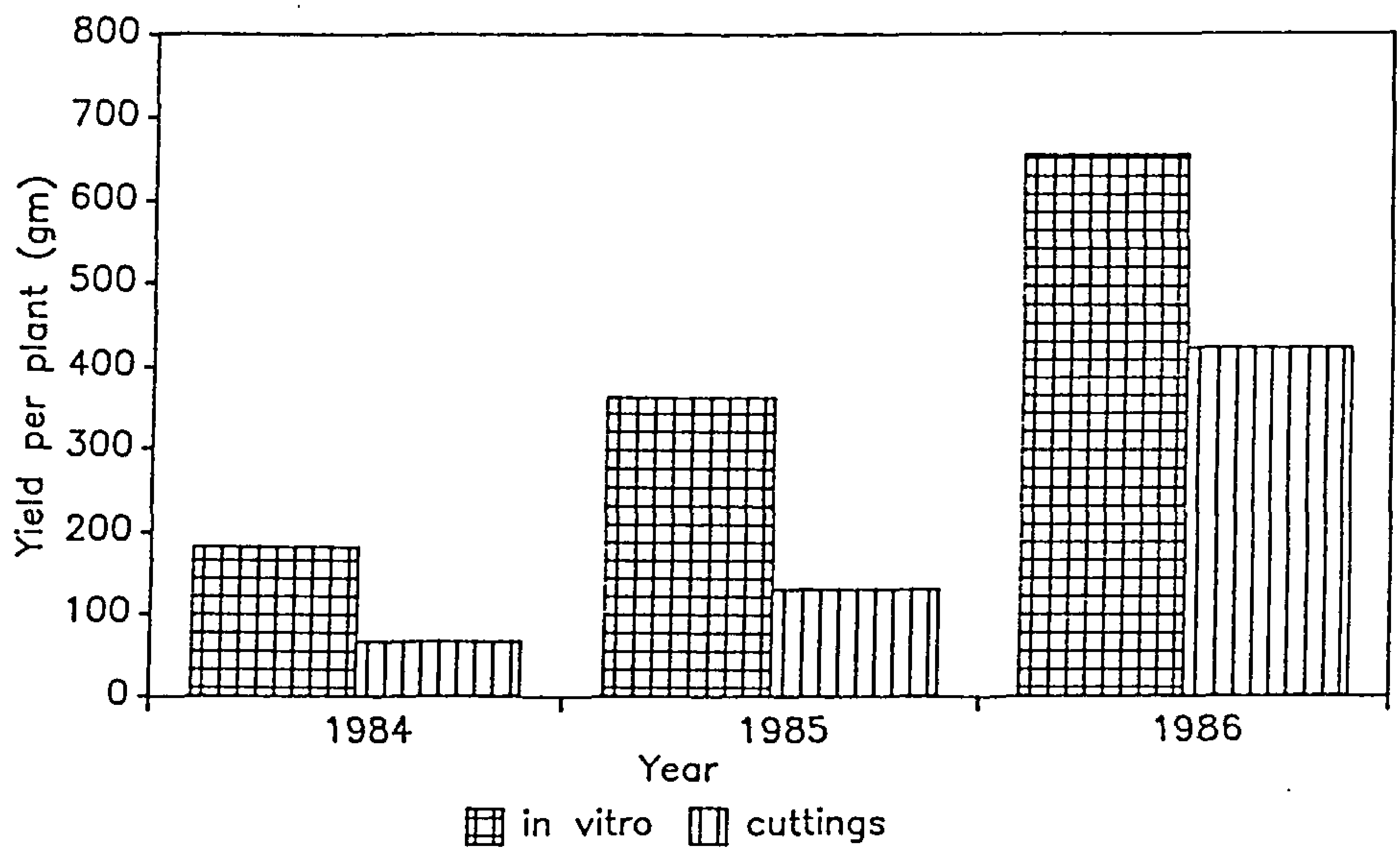

Figure 1. Effect of propagation method on yield of 'Northblue' blueberries field-planted June 1, 1983.

This research is significant for a number of reasons. Since *in vitro* propagation of these types of blueberries is more efficient and cost effective than conventional propagation, it is critical that they perform in an equivalent or superior manner to the conventionally propagated plants. The fact that they actually outperform conventionally propagated plants should facilitate economic establishment of commercial plantations that begin to pay a return on the investment at an earlier date than would be the case for conventionally propagated plants.

Figure 2. Growth habit of 'Northblue' blueberry plants propagated by cuttings (*left*) and by *in vitro* methods (*right*).

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ROLE OF SHOOT GROWTH AND AMMONIUM NITRATE FERTILIZER ON ENDOGENOUS CARBOHYDRATE, AMMONIUM, AND NITRATE LEVELS OF NEWLY-ROOTED *ACER PALMATUM* CUTTINGS

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Abstract. Ammonium nitrate (NH_4NO_3) fertilization and shoot growth of *Acer palmatum* 'Bloodgood' were studied to determine their effects on carbohydrates and endogenous ammonium (NH_4) and nitrate (NO_3) levels. Generally, an inverse relationship existed between tissue NH_4 and NO_3 levels and soluble sugars (fructose, glucose, and sucrose). Exceedingly high NH_4 and concomitantly low soluble sugar amounts were apparent, especially in plants lacking new shoot growth and given N after rooting. Increasing the N rate magnified these trends. Plants with new shoot growth and given N maintained higher soluble sugar levels and lower NH_4 levels than plants without growth. These amounts remained relatively unchanged as N rate increased. Nitrogen had no effect on starch levels. These results suggest that plants without shoot growth have low tolerance to NH_4NO_3 fertilization, and are subject to NH_4 toxicity brought about by a decrease in available carbohydrates. Plants with new shoot growth were able to assimilate large amounts of NH_4 without harmful effect, while at the same time increasing shoot growth.

REVIEW OF LITERATURE

The low overwinter survival of rooted cuttings of certain deciduous woody plants such as *Acer, Cornus, Hamamelis, Magnolia, Prunus, Rhododendron,* and *Viburnum* is a significant problem. Cuttings will root and appear alive and dormant in the autumn, but either die the first winter or after budbreak in the spring (4,5,6,7,9,12,13).

Propagation time, nitrogen, and shoot growth were recently found to affect overwinter survival of newly-rooted stem tip cuttings of *Acer palmatum* 'Bloodgood' and *Cornus florida* var. *rubra* (9,20,21). Propagation of *A. palmatum* and *C. florida* in May and June, respectively, resulted in a greater number of plants with shoot growth after rooting compared to those propagated later. May propagation of *A. palmatum* resulted in reduced overwinter survival while propagation date did not significantly affect overwintering of *C. florida* when N was excluded, regardless of shoot growth. Plants with shoot growth receiving N had higher survival, but less than those with shoot growth and not given N. Poorest overwintering occurred on both species given N that failed to grow prior to winter storage.

The objective of this research was to determine the relationship of shoot growth and NH_4NO_3 fertilizer on endogenous levels of NH_4 and NO_3 nitrogen, and soluble carbohydrates.

MATERIALS AND METHODS

Primary shoot tip cuttings of *A. palmatum* 'Bloodgood' were taken at Angelica Nursery Inc., Chesterville, Maryland on 22 May, 1985. Cuttings were momentarily submerged in water, wrapped in moist burlap and plastic and placed in wooden flats in the shade. Upon return to the University of Maryland, they were resubmerged in water, again wrapped in burlap and plastic and stored at 4°C overnight.

Cuttings were recut to 20 cm and basal leaves were removed so that 4 or 5 fully expanded leaves remained. To aid rooting, four 2.5 cm vertical basal wounds through the cambium were made with a razor blade and the cuttings were dipped in water and treated with a commercial talc powder preparation of indole-3-butyric acid at 20,000 $mg \cdot g^{-1}$ (Hormo-Root 2; Hortus Products Inc., Newfoundland, New Jersey). Cuttings were placed in a moistened rooting medium composed of coarse perlite and sphagnum peat (3:2, v/v). To reduce transplant shock, cuttings were placed in styrofoam "Speedling" (Speedling Manufacturing, Inc., Sun City, Florida) trays with individual 3.75 × 3.75 × 12.5 cm compartments, and rooted under intermittent mist in the greenhouse.

After about 5 weeks, rooted cuttings (roots about 2.5 cm or longer) were transplanted into 10.2 cm square plastic pots (0.5 liter volume) with sphagnum peat and coarse perlite medium (3:2, v/v) amended with 7.5 g fritted trace elements #503, 525.0 g dolomitic limestone, 88.5 g 0N-44 P_2O_5-0K_2O, and 77.9 g 0N-0P_2O_5-50 K_2O per 50 liters medium. The medium pH was 6.3. Potted plants were acclimated under decreasing levels of mist for 2 weeks.

After transplanting and acclimation, plants were placed in the greenhouse under an 18 hr photoperiod with day continuation (1600–0200HR) from 100 W incandescent bulbs placed 2 m apart and 1.1 m above the plants (9 $\mu mols\ s^{-1}m^{-2}$). Nitrogen treatments were applied as NH_4NO_3 once weekly at 0, 100, 200, and 400 $mg \cdot liter^{-1}$. Pots were fertilized to runoff with ca 150 ml fertilizer solution. Water was provided to all plants in equal amounts between fertilizer applications.

Plants were arranged in a split-plot design with 2 blocks. Nitrogen was the whole plot. Within each whole plot, randomly selected plants had a terminal leaf and petiole removed (10 July, 1985) to expose the subtending bud and promote apical growth (9). This determined the subplot grouping: growth vs. no growth.

Plants were harvested 25 October, 1985 and roots and stems with and without shoot growth after rooting were analyzed for NH_4 and NO_3 nitrogen, and for sucrose, glucose, fructose, and starch. Detailed description of analysis procedures are described elsewhere (17).

RESULTS

Ammonium in roots and stems was influenced by a significant N × growth interaction (Fig. 1) (17). Plants with growth which received N had NH_4 levels slightly higher than treatments without N. Increases in N rate on plants which grew had no significant effect on root or stem NH_4 content. If *A. palmatum* 'Bloodgood' failed to grow after rooting and N was not provided, root and stem NH_4 levels were low and similar to those which grew and did not receive N. Increasing N rate to plants without growth resulted in sharp increases of NH_4 in root and stem tissues. Highest NH_4 concentrations were found in stems.

Nitrate levels in roots and stems were affected by a significant N × growth interaction (Fig. 1) (17). As N rate increased, root NO_3 increased further in plants which grew than those without growth. Additional stem NO_3 was found in plants without shoot growth as N rate increased, compared to those with growth. Highest NO_3 concentrations were found in roots.

Carbohydrates of roots and stems were influenced by N rate

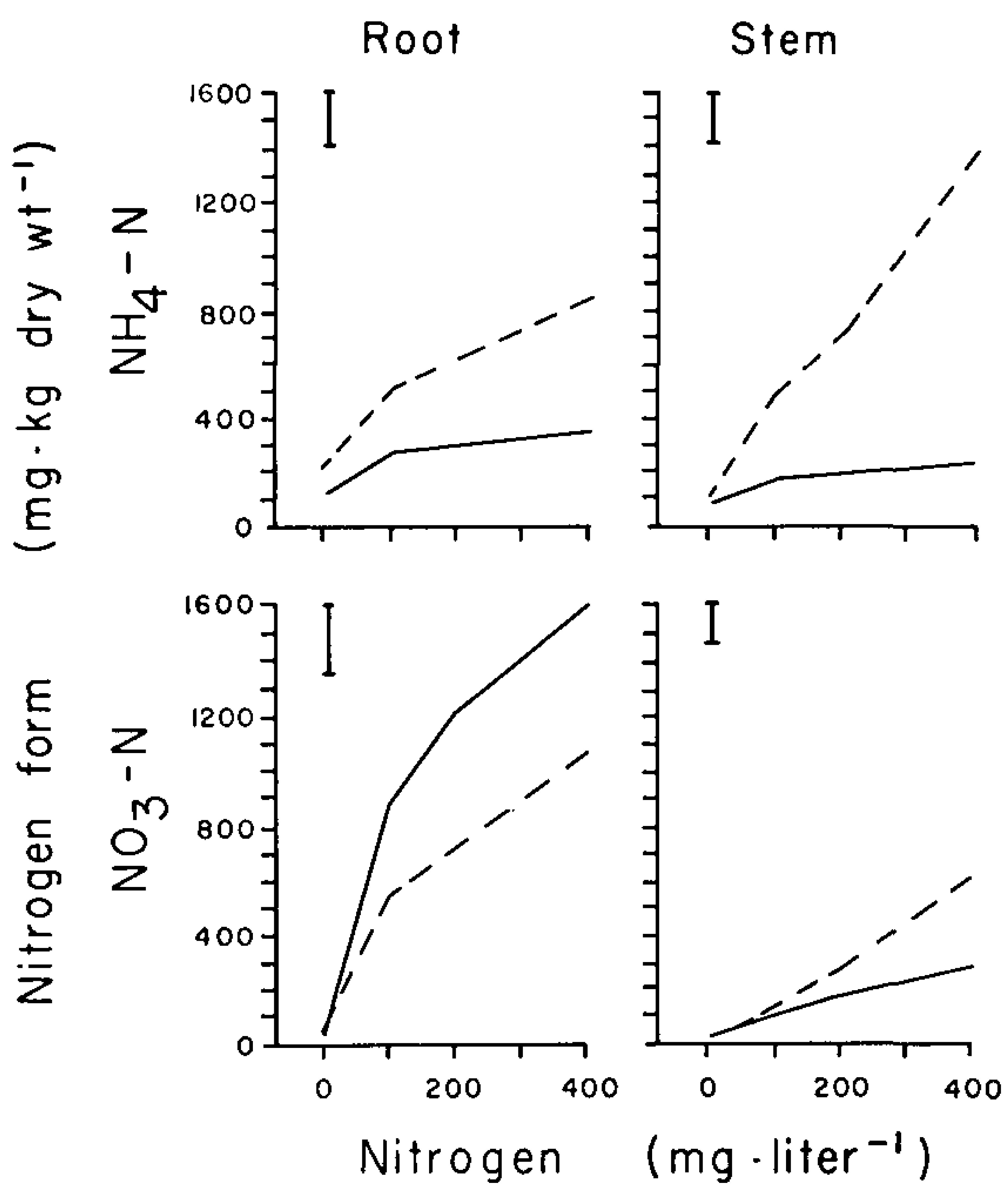

Figure 1. Ammonium and nitrate accumulation in roots and stems of rooted *Acer palmatum* 'Bloodgood' stem tip cuttings in response to nitrogen rate and plant growth. Lines represent plants with (———) and without (----) shoot growth after rooting. Vertical bars represent Fisher's LSD.

and shoot growth after propagation (17). Root fructose and glucose content and stem glucose were affected significantly by N and growth, and stem fructose by a N × growth interaction. A N × growth interaction for root and stem sucrose was significant (17). Plant starch levels were not affected by nitrogen, but were influenced by plant growth, as seen in stem tissues.

Fructose and glucose levels of roots and stems were highest when treatment excluded N (Fig. 2). These levels were reduced sharply by addition of 100 mg·liter $^{-1}$ N, and were depleted further (though more slowly) by higher N rates. Nitrogen had little effect on root and stem sucrose in plants which grew. Regardless of N, plants with shoot growth after rooting generally maintained higher sucrose levels than plants without growth that were given N. No clear trend in starch level was apparent, regardless of shoot growth or N rate.

DISCUSSION

These data suggest that endogenous NH_4 and NO_3 levels, and fructose, glucose, and sucrose levels were associated with NH_4NO_3 fertilization rate and shoot growth response after rooting of *A. palmatum* 'Bloodgood' stem cuttings. Generally, an inverse relationship existed between tissue NH_4 and NO_3 levels, and soluble sugars. Exceedingly high tissue NH_4 and concomitant low soluble sugar concentrations were apparent, especially on plants lacking new shoot growth and given NH_4NO_3 after rooting (Figs. 1 and 2). Increasing the N rate enhanced the magnitude of separation between these trends. Since NH_4 assimilation into amino acids has a carbohydrate requirement (1,14,16,18), NH_4NO_3 fertilization would be expected to deplete carbohydrate levels. *Acer palmatum* with shoot growth and given NH_4NO_3 maintained higher soluble sugar levels and lower NH_4 levels than plants without growth. Interestingly, on plants with growth, the levels of endogenous NH_4 and soluble sugars remained relatively unchanged as NH_4NO_3 was increased. This suggests that, as a result of shoot growth, soluble sugar levels were sufficient to offset the carbohydrate demands of NH_4 assimilation brought about by NH_4NO_3 fertilization. If plants produced no shoot growth after propagation, low soluble sugar levels may have prevented assimilation of all cellular NH_4 allowing toxic amounts to accumulate.

Any role of starch in NH_4 assimilation remains unclear. Increasing NH_4NO_3 rate had no significant effect on endogenous starch levels in roots, stems or new shoots, even after NH_4 had reached toxic levels. Perhaps *A. palmatum* maintains its starch reserves at a given level, and must assimilate NH_4 at the expense of other carbohydrates. The rooted cuttings may be unable to hydrolyze starch into glucose, and must rely solely on existing fruc-

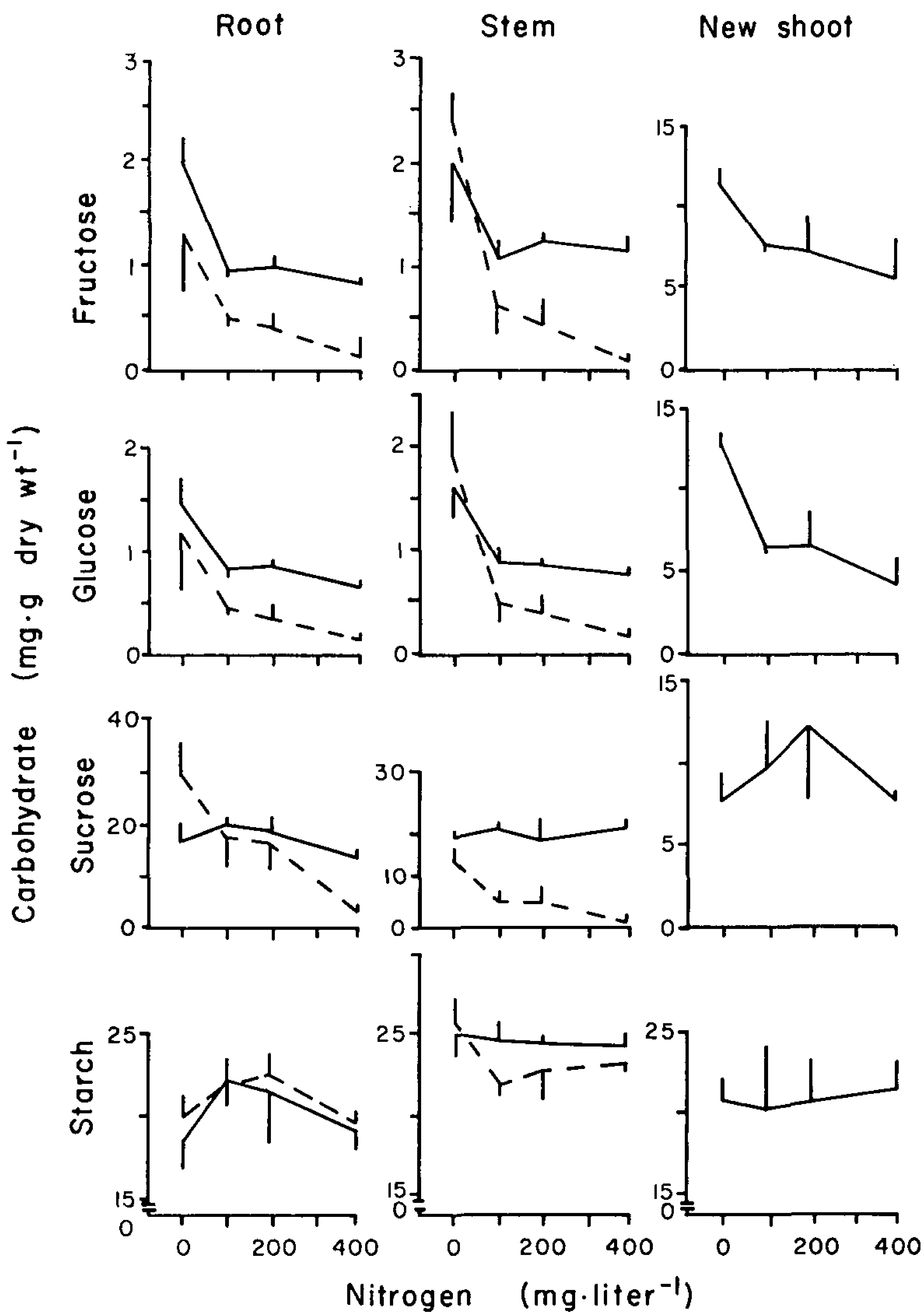

Figure 2. Influence of nitrogen rate and plant growth on carbohydrate levels in roots and stems of rooted *A. palmatum* 'Bloodgood' stem tip cuttings. Lines represent plants with (——) and without (----) shoot growth after rooting. Vertical bars represent standard errors.

tose, glucose, and sucrose as a carbon source for NH_4 assimilation. In contrast, in research with *A. rubrum* 'October Glory', starch levels increased in plants which grew after rooting (19). However, the role of nitrogen was not part of this study.

Once taken into the root, NH_4 is usually assimilated immediately into non-toxic glutamine (8). If inadequate carbohydrate supplies delay complete assimilation, however, NH_4 ions can accumulate in roots (18). This NH_4 may be transported to the stems and leaves, where it effects can be especially deleterious (2). Apparently this was the case in *A. palmatum*, where plants given NH_4NO_3 without shoot growth accumulated NH_4 in both roots and stems (Fig. 1). There were no increases in root or stem NH_4 in plants that grew. Increases in shoot NH_4 may be due to accelerated transpiration (and nutrient uptake) in plants with new growth. High transpiration has been associated previously with accumulation of shoot NH_4 sometimes in quantities sufficient to trigger NH_4, toxicity through uncoupled photophosphorylation (1,10,11).

Nitrate N, which is non-toxic, may be accumulated safely in cell vacuoles in relatively large quantities (1). Since NO_3 must be reduced before assimilation can occur, its usage requires more energy than NH_4 assimilation. Because of this, regulatory mechanisms within the plant limit NO_3 assimilation, periods of optimum efficiency (3). Nitrate reduction in roots occurs only when there is sufficient carbohydrates to produce the energy required for reduction and, at the same time, carbon skeletons for assimilation (15). The present data show that NO_3 is apparently not as mobile as NH_4 within *A. palmatum*, and accumulates in the roots after absorption (Figure 1). This finding may indicate the location of NO_3 reduction in the plant. Since NO_3 reductase is an adaptive enzyme, and is found only in the presence of NO_3, it probably exists in the highest quantities in the roots of *A. palmatum*. Plants with new shoot growth were found to accumulate larger quantities of NO_3 than plants lacking shoot growth, perhaps due to increased uptake of soil solution.

The results of this research indicate that plant growth after rooting of *A. palmatum* stem cuttings is essential to survival of plants receiving N. If new growth is initiated, plants may be fertilized with up to 200 mg•liter^{-1} N (as NH_4NO_3) without appreciable decrease in survival (17). If plants do not grow after rooting, NH_4NO_3 fertilization should be avoided, since lower survival is eminent.

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VEGETATIVE PROPAGATION OF THE THREATENED HALOPHYTE, *MALLOTONIA GNAPHALODES*

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Abstract. The dune inhabiting halophyte, *Mallotonia gnaphalodes* (sea-lavender) is threatened with extinction, with less than ten colonies left in the continental southeastern United States and many more colonies on islands in the Bahamas and Caribbean. The major barrier to widespread use of this plant in coastal landscape applications, including dune stabilization programs, has been difficult propagation. The objective of this project was to develop successful vegetative propagation techniques for sea-lavender. Successful rooting of cuttings was accomplished using fog propagation, 8,000 ppm indolebutyric acid, and a well-aerated rooting medium.

INTRODUCTION

The halophyte, *Mallotonia gnaphalodes* (sea-lavender) is threatened with extinction due to extensive, unrestricted development which has eliminated most of its dune habitat in southeastern Florida. Currently, there are less than ten colonies left on the continental United States, with many more reported in the Bahamas and Caribbean islands (2). Sea-lavender is an important dune stabilizer, but also has many aesthetic characteristics which give the plant a great potential for more general landscape use.

Sea-lavender is a very beautiful shrub up to 2 m tall, with slender grey-green, pubescent leaves (1,2). It grows in smoothly rounded clumps up to 7 m wide and would be an interesting addition to the list of plants available for use in xeriscapes.

The main limiting factor in the widespread production and use of sea-lavender is difficult propagation. A preliminary test using 1,000 field-collected seeds, provided by the State of Florida's Department of Natural Resources, showed virtually no seeds germinated under the usual germination environment. Nurserymen reported similar germination problems and also indicated difficulty in vegetative propagation from cuttings.

Since field specimens were observed to layer naturally, vegetative propagation of sea-lavender was the focus of this study. The objective of this project was to investigate parameters which could be manipulated to improve the success of vegetative propagation.

VEGETATIVE PROPAGATION

An experiment designed to determine whether mist or fog propagation was superior for vegetative propagation of sea-lavender was initiated. Fog propagation proved to be superior, with

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nearly all cuttings rooting under fog at 90% relative humidity, but none under a standard mist system. Apparently the increased humidity of fog propagation is a key factor in overcoming the initial problem of vegetative propagation.

An experiment designed to determine the optimum auxin treatment compared 0, 1,000, and 8,000 ppm indolebutyric acid (IBA) as talc preparations. Cuttings treated with 8,000 ppm IBA prior to sticking rooted best.

Finally, an experiment was conducted which compared four propagation media for use in cutting propagation. The four media tested were: sewage sludge compost, sphagnum peat moss: perlite: vermiculite (3:1:1, v/v/v), sand, and perlite. Results indicated that a light, well-aerated mix such as the sphagnum peat moss: perlite: vermiculite mix is best, although sewage sludge compost and sand both were effective when no rooting hormone was applied. A mixture of sewage sludge compost and perlite might also be effective.

Based on these findings, the optimum rooting conditions for sea-lavender cuttings are fog propagation, an 8,000 ppm auxin application, and a well-aerated rooting medium.

REVEGETATION

While these results are promising for the successful vegetative propagation of sea-lavender, there are also problems with establishment of the plants, particularly if the growing medium is one which does not drain readily. This problem should be solvable through work investigating growing media following propagation.

The outlook for existing dunes and native plants looks bright, as there is currently an increasing public realization of their importance. This is complemented by the creation of programs to preserve existing dunes through limits on construction, creation of walkways to guide people over the dunes without destroying them, and replanting efforts. With continued work, sea-lavender and other dune inhabitants will continue to be representative of this important halophytic environment.

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DESIGNING A PLANT MICROPROPAGATION LABORATORY

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Tissue culture is rapidly becoming a commercial method for propagating new cultivars, rare species, and difficult-to-propagate plants. From a few research laboratories several years ago, a whole new industry is emerging. Currently, the demand for micropropagated plants is greater than the supply with some plants. Some growers specialize in only the micropropagation of plantlets, leaving the growing-on to others; many growers are integrating a tissue culture laboratory into their overall operation.

In designing any laboratory, big or small, certain elements are essential for a successful operation. The correct design of a laboratory will not only help maintain asepsis, but it will also achieve a high standard of work.

FACILITIES

Careful planning is an important first step when considering the size and location of a laboratory. It is recommended that visits be made to several other facilities to view their arrangement and operation. A small lab should be set up first until the proper techniques and markets are developed.

A convenient location for a small lab is a room or part of the basement of a house, a garage, a remodeled office or a room in the headhouse. The minimum area required for media preparation, transfer and primary growth shelves is about 150 sq ft. Walls may have to be installed to separate different areas.

A good location includes the following:

1) Isolation from foot traffic.
2) No contamination from adjacent rooms.
3) Thermostatically controlled heat.
4) Water and drains for a sink.
5) Adequate electrical service.
6) Provisions for a fan and intake blower for ventilation.
7) Good lighting.

Larger labs are frequently built as free-standing buildings. Although more expensive to build, the added isolation from adjacent activities will keep the laboratory cleaner.

Prefabricated buildings make convenient low cost laboratories. They are readily available in many sizes in most parts of the coun-

[1] Assistant Professor and Extension Professor, respectively.

try. Built-in-place frame buildings can also be used. Consideration should be given to the following:

1) Check with local authorities about zoning and building permits.
2) Locate the building away from sources of contamination such as a gravel driveway or parking lot, soil mixing area, shipping dock, pesticide storage, or dust and chemicals from fields.
3) A clear span building allows for a flexible arrangement of walls.
4) The floor should be concrete or capable of carrying 50 pounds per square foot.
5) Walls and ceiling should be insulated to at least R-15 and be covered inside with a water-resistant material.
6) Windows, if desired, may be placed wherever convenient in the media preparation and glassware washing rooms.
7) The heating system should be capable of maintaining a room temperature at 70°F in the coldest part of winter.
8) A minimum ¾ in. water service is needed.
9) Connection to a septic system or sanitary sewer should be provided.
10) Air conditioning for summer cooling may be necessary.
11) Electric service capacity for equipment, lights and future expansion should be calculated. A minimum 100 amp service is recommended.

GENERAL LABORATORY DESIGN

Cleanliness is the major consideration when designing a plant tissue culture laboratory. Most companies are not aware of their losses from contamination, but estimates run from less than 1% up to 50%. When you consider the high value of the product, no losses from contamination are acceptable. Routine cleaning and aseptic procedures can decrease your losses to less than 1%. Laboratories should have easy to wash walls and floors. Acrylic or urethane epoxy wall paints can be used; cement floors can be painted with an epoxy or urethane floor enamel or have an inlaid linoleum installed. High efficiency particulate air (HEPA) filters or regular furnace filters can be installed over air intakes to the laboratory or on furnaces. If possible, an enclosed entrance should precede the laboratory; sticky mats can be laid there to help collect dirt from the outside, or shoes can be removed.

The traffic pattern and work flow in a laboratory must be considered in order to maximize cleanliness. The cleanest rooms or areas are the culture room, i.e. primary growth room, and the aseptic transfer area. It is best to design these rooms so they are not entered directly from the outside of a building. The media preparation area, glassware washing area, or storage area should be located outside these rooms. The primary growth room and aseptic transfer room should be enclosed with doors leading to each. Traffic through these areas can be minimized by installing pass-through windows. Ideally, the media preparation area would lead to the sterilization area, which would lead to the aseptic transfer room and eventually the primary growth room.

Unusual requirements for electricity and fire safety dictate that power installation be done by professional electricians. Most wiring will require 110 volts, but water treatment equipment and autoclaves may require 220 volts. Temperature and fire alarms are to be connected directly to telephone lines to give fast warnings of problems. An emergency generator should be available to operate essential equipment during power outages.

GLASSWARE WASHING AND STORAGE AREA

The glassware washing area should be located near the sterilization and media preparation areas. When culture vessels are removed from the growth area, they are often autoclaved to kill contaminants or to soften semi-solid media. The vessels can be easily moved to the washing area if the autoclave or pressure cooker is nearby. Locate the glassware storage area close to the wash area to expedite storage; these areas also need to be accessible to the media preparation area.

The glassware area should be equipped with at least one large sink; two sinks are preferable. Adequate work space is required on both sides of the sink; this space will be used for glassware soaking tubs and drainage trays. Plastic netting can be placed on surfaces near the sink to reduce glassware breakage and enhance water drainage. The pipes leading from the sink can be PVC to resist damage from acids and alkalis. Both hot and cold water should be available with water distillation and/or deionization devices nearby. Mobile drying racks can be stored nearby and lined with cheesecloth to prevent water dripping and loss of small objects. Locate ovens or hot air cabinets (75°C) close to the glassware washing and storage area. Dust-proof cabinets, low enough to allow easy access, can be used in the storage area.

MEDIA PREPARATION AND STERILIZATION AREA

The water source and glassware storage area should be convenient to the media preparation area. Benches, suitable for comfortable working while standing (34 to 36 in.) and deep enough (24 in.) to hold equipment listed below are essential. Their tops should be made with molded plastic laminate surfaces that can tolerate frequent cleanings.

There is a variety of equipment available for micropropagation laboratories; this equipment is generally located in the media preparation area. The equipment budget will determine the type and amount purchased. All laboratories need the following basics:

1) Refrigerator/freezer—This is needed to store chemicals and stock solutions. Small laboratories may find it adequate to use countertop refrigerators.
2) High quality water—Bottled water can be purchased inexpensively and placed in the media preparation area. Larger businesses may find it economical to obtain distillation or deionization devices; these would normally be located in the glassware washing area. Small, inexpensive, low production Pyrex distillation devices can be purchased by small businesses that want the convenience of a still, but not the cost.
3) Balances—High quality balances are essential for a micropropagation laboratory; this is one area where it is difficult to find an inexpensive substitute. A triple beam balance is useful for large amounts over 10 grams, but a balance that can measure down to 2 mg is essential. Most laboratories have both a microbalance and a less sensitive top loading balance; the latter can be used more quickly and efficiently for less sensitive quantities.
4) Hot plate/stirrer—At least one ho, plate with an automatic stirrer is needed to make semi-solid media. This purchase can be eliminated by using a stove and hand stirring the media while it heats; however, the time saved by using a stirring hot plate is worth the money spent.
5) pH meter—This is needed to measure media pH. Some laboratories use pH indicator paper, however this method is considerably less accurate and could severely affect the results.
6) Aspirator or vacuum pump—Aspirators can be easily attached to a water source and used for filter sterilization of chemicals. They are also used to disinfest plant material. Vacuum pumps are faster and more efficient, but also more expensive.
7) Autoclave—An autoclave or pressure cooker is a vital part of a micropropagation laboratory. High pressure heat is needed to sterilize media, water, glassware, and utensils. Certain spores from fungi and bacteria will only be killed at a temperature of 121°F and 15 pounds per square inch (psi). Self generating steam autoclaves are more dependable and faster to operate.
8) Optional equipment—A variety of non-essential equipment is available for tissue culture laboratories; individual

needs and equipment cost will determine what can be purchased. Microwave ovens are convenient for defrosting frozen stocks and heating agar media. Dissecting microscopes are useful to have in the laboratory for meristeming, dissecting floral and shoot apices, and observing plant culture growth. Labwashers, or regular dishwashers, can be useful. Automatic media dispensers are helpful when pipetting large volumes of media.

PRIMARY GROWTH ROOM

Temperature, relative humidity, lighting units, and shelves need to be considered in the culture room. All of these environmental considerations will vary depending on the size of the growth room, its location, and the type of plants grown within it. For example, a small primary growth room located in a cool, North American climate, can be placed in an unheated or minimally heated basement. The ballasts from the fluorescent lights do not need to be separated; rather they can be used as a heating source. Excess heat can be blown out of the growth room and used to heat other parts of the basement or building. In this case, solid wood shelves with air spaces located between shelves are recommended to prevent the cultures on shelves above lights from becoming overheated. A larger growth room located in an above-ground location may need to have remote ballasts and/or a heat pump installed. Shelves in a larger growth room could then be glass or expanded metal.

Temperature is the primary concern in culture rooms; it affects decisions on lights, relative humidity, and shelving. Generally, temperatures are kept 76° ± 2°F. Heating can be accomplished by traditional heating systems supplemented with heat from light ballasts or space heaters. Cooling the room is usually a greater problem than heating; cooler temperatures can be obtained by installing heat pumps, air conditioners, or exhaust fans. Using outside windows to cool culture rooms invites contamination problems in the summer and humidity problems in the winter.

Some plant cultures can be kept in complete darkness; however, most culture rooms are lighted at 1 klux (approximately 100 ft-c) with some going up to 5 to 10 klux. The plant species being micropropagated will determine the intensity used. The developmental stage of the plants will also help determine if wide spectrum or cool white fluorescent lights are used. Rooting has been shown to increase with far-red light; therefore, wide spectrum lights should be used during stage III and cool-white lights can be used during Stages I and II. Automatic timers are needed to maintain desired photoperiods. Reflectors can be placed over bulbs to direct their light. Heat generated by the lights may cause condensation and temperature problems. In addition to using procedures previously mentioned, small fans with or without polyethylene tubes attached, can be placed at the ends of shelves to increase air flow and decrease heat accumulation.

Relative humidity (RH) is difficult to control inside growing vessels, but fluctuations in the culture room may have a deleterious effect. Cultures can dry out if the room's RH is less than 50%; humidifiers can be used to correct this problem. If the RH becomes to high, a dehumidifier is recommended.

Shelving within primary growth rooms can vary depending upon the situation and the plants grown. Wood is recommended for inexpensive, easy-to-build shelves. The wood for shelves should be exterior particleboard or plywood and should be painted white to reflect the room's light. Expanded metal is more expensive than wood, but provides better air circulation; wire mesh of 1/4 or 1/2 in. hardware cloth can be used but tends to sag under load. Tempered glass is sometimes used for shelves to increase light penetration, but it is more prone to breaking. Air spaces, 2 to 4 in., between the lights and shelves will decrease bottom heat on upper shelves and condensation in culture vessels. A room that is 8 ft high will accommodate 5 shelves, each 18 in. apart, when the bottom shelf is 4 in. off the floor. The top and bottom shelves may be difficult to work.

ASEPTIC TRANSFER AREA

In addition to the primary growth room, the aseptic transfer area needs to be as clean as possible. It is preferable to have a separate room for aseptic transfer; this decreases spore circulation and allows personnel to leave shoes outside the room. Special laboratory shoes and coats should be worn in this area. Laminar flow hoods or still-air boxes can be placed in this room and used for all aseptic work. Ultraviolet (UV) lights are sometimes installed in transfer areas to disinfect the room; these lights should only be used when people and plant material are not in the room. Safety switches can be installed to shut off the UV lights when regular room lights are turned on. Surfaces inside the aseptic transfer area should be smooth to minimize the amount of dust that settles. Several electric outlets are to be installed to accommodate balances, flow hoods, bacti-cinerators, and microscopes.

PROPAGATION OF SOME WOODY ENDEMIC PLANTS OF EASTERN NORTH AMERICA

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The native flora of eastern North America has a number of rare woody plants that are under-represented in botanical gardens and may also have commercial potential for the nursery trade. I would like to share some of what I have learned about ten of these, and where possible, supply propagation material to anyone interested.

This work reflects research done by the Arnold Arboretum and sponsored by the Center for Plant Conservation. I would like to thank intern Laurie Sullivan for her assistance in these trials.

The rarest conifer in North America is probably the stinking cedar, *Torreya taxifolia*. A member of the yew family, it is found in only four counties of the Florida panhandle and possibly southwestern Georgia. Trees of 40 ft were reported previously but now, due to a blight, adult trees are dying in native stands and extinction is a real possibility. Determining the effective propagation of this species might be a matter of some importance if the species is to survive at all.

From cuttings taken in mid-autumn, I was able to get decent rooting. Cuttings were placed in a poly tent in a mix of coarse sand and perlite (1:1, v/v), bottom heated to 75°F, and examined after 2 months.

A small quantity of cuttings were taken from five, different small plants. IBA-talc powder (8000 ppm) was used on 40 cuttings with 5000 ppm IBA alcohol dip used for another 40 cuttings. IBA powder showed an overall rooting percentage of 54% with the IBA dip showing 65%. No real qualitative difference between the roots in each lot was apparent. Rooted cuttings showed a strong tendency to grow laterally if the cuttings were initially from lateral branches. Unless the original cutting was from a leader, reestablishment of a new leader took a year or two.

Propagation from seed is more problematic as they are hard to obtain. The Biltmore Estate in Asheville, North Carolina has a stand of mature trees and may be the only source of seed in the country as trees in the world no longer seem to be setting seed.

Our records at the Arnold Arboretum show poor seed germination with *Torreya* in general and what literature exists cites long periods of time between sowing and eventual germination. I am presently in the middle of a seed trial with 11 different treatments and hope to report on my results at a future time.

Another rare member of the yew family that is found only in two counties of the Florida panhandle is the Florida yew, *Taxus floridana*. I have only seen one plant, a multi-stemmed shrub of 10 feet situated alongside a stream, but trees of 25 ft have been reported. Foliage is thin, dark green, and about an inch long. Wild fall-collected cuttings from a mature wild plant in deep shade showed 57% rooting when treated with 8000 ppm IBA powder, under poly, in sand and perlite (1:1, v/v). Cuttings subsequently taken from these rooted cuttings rooted in much higher percentages the following year.

Cuttings were taken in late December, placed in sand and perlite (1:1, v/v) under poly with bottom heat. All cuttings were rated in mid-April: 10,000 ppm IBA alcohol dip rooted 100%, 8000 ppm IBA powder rooted 90%, and control rooted 80%. The Florida yew has survived one winter outside in Boston, surviving a low of −1°F.

The foliage, however, shows a tendency to change color when exposed to cold temperatures, changing to a purple-brown as early as October. The heat tolerance of this yew may make it a potential ornamental for southern states.

Of the eight American magnolias, *Magnolia ashei* is the rarest, being found only in the Florida panhandle. Despite this southerly distribution, it has proven hardy in Boston, like a number of other plants from this region. It is found in deep shade usually as an understory plant but can reach a height of 25 ft. It is often multi-stemmed and has a short, broad, gangly, open habit.

Leaves of this magnolia are huge, measuring over 2 ft long and almost one foot wide. Its flowers are equally outsized with a diameter of 12 in.

This species is reported to grow and bloom well in shade. The plant, therefore, may be an interesting choice for courtyard planting or as an understory plant. Cuttings taken in late July produced no roots. Treatments included: 6000 ppm K-IBA dip, sand and perlite (1:1; v/v); 6000 ppm K-IBA dip, pumice mix (#10 grade pumice, perlite, peat [6:3:1, v/v/v]); and control in sand/perlite. A final treatment was tried, one with which I have had great success with other species of magnolia. A flat wooden toothpick, soaked in 6000 ppm K-IBA, was inserted longitudinally up into the soft pith of the cutting. About ⅓ to ½ in. of toothpick was inserted, then the remainder trimmed off.

Budding would best be done by chip budding onto hardy magnolias of the Rytidospermum section, i.e. *M. macrophylla*, *M. fraseri*, *M. tripetala*, or *M. hypoleuca*.

Seed germinates if given a cold stratification period of 6 to 12 weeks' duration. Germination occurred 6 weeks after sowing.

Ilex collina, the long-stalked holly, is a deciduous shrub of great ornamental potential that is found in West Virginia, Virginia, and North Carolina. I have seen populations in West Virginia and

Virginia and judging from the trees seen with it (spruce, fir, and hemlock) it should demonstrate good hardiness. The plant itself is a multi-stemmed species growing to 10 ft. The main ornamental attribute of this holly is its large fruit, about 8 mm in diameter and held on a long peduncle 3/8 to 5/8 in. long. Fruit ranges in color from dark scarlet-red to orange to a yellow-fruited form, *Ilex collina* f. *van trompii*.

A cutting trial was set up using three different media: sand and perlite (1:1, v/v); peat and perlite (1:1, v/v); and pumice mix. Cuttings were taken in mid-July, given a treatment of 8000 ppm IBA powder, and placed under an intermittent mist system. Cuttings were rated in mid-October and little difference was evident among media. Controls and all hormone treatments rooted 100% with little qualitative difference. Leafless fall cuttings stuck in pumice mix, after treatment with 8000 ppm IBA powder also rooted 100%.

A seed germination trial was conducted with fresh, wild-collected, seed from a West Virginia population. Lots from 18 plants were given treatments including direct sowing; a three-month cold stratification; five months warm stratification, followed by three months cold; and three months warm, followed by two months cold. Results after one year are mixed. Fresh sown seed has produced both seedlings and seed with just radicle emerged. Similar results were obtained from the 3 month cold treatment. Treatments that started with a warm stratification, often had seeds producing radicles in the bag prior to the cold treatment; therefore, in many cases, the cold treatment was skipped. In general, it appeared that the seed lots that received any length of warm stratification, whether followed by cold stratification or not, had produced more seedlings after one year.

Ilex amelanchier, the sarvis or satinberry holly, is another rare deciduous holly of the southeast coastal plain. It inhabits woody stream banks and sand hills in sporadic stands from North Carolina to Louisiana. A shrub, or rarely a small tree, it features a soft-green foliage and a fruit that, at maturity, is a striking rose-purple color with a satiny rather than glossy finish. This species has withstood below zero temperatures in Boston. The specimens we have are not heavy fruiting, so there is room for some selection with this species. A cutting trial was started in mid-July using cuttings from a ten-year old plant. The treatments were the same as those with *Ilex collina*. The following results were obtained: for the peat mix, both control and treated cuttings rooted 100%; for the sand mix, the treated cuttings rooted 100%, control 0%; and for the pumice mix, treated cuttings rooted 86%, control 100%. Qualitatively, the peat mix produced better roots and seems to be the best for this species.

A seed trial was also conducted with the following results: Direct sowing yielded 36% germination as compared to 68% germination after a three-month cold stratification treatment. Seed lots were also given warm stratification, followed by cold stratification treatments. A 5 month warm plus 3 month cold (5W, 3C) treatment germinated 64% and with a 3W, 2C treatment seed germinated 72%. In short, it seems to be a very easy holly to get good seed germination as long as it receives a cold treatment.

Conradina verticillata, the Cumberland rosemary, is a low growing shrub native to Big South Fork and Obed River drainages of the Cumberland Plateau in Tennessee and Kentucky. It is found on sandy gravel bars in full sun, although during flood stage the plant is totally underwater.

The Cumberland rosemary, although highly ornamental, has received only limited testing and its tolerance to cold is still unclear. One botanist, Howard Pfieffer, grows the plant successfully in Zone 5 in Mansfield Center, Connecticut. It features small, purple-pink to whitish flowers, and shows both upright and more prostrate forms. These prostrate forms deserve trial as a ground cover.

This is the easiest plant to root I have ever handled. Two hundred and forty fall-cuttings were collected from 20 different plants. The cuttings were treated with 4000 ppm IBA powder, stuck in a poly tent with bottom heat and a medium of sand and perlite (1:1, v/v). Two hundred thirty-six cuttings, or 98%, rooted with a good to excellent rating.

I have never seen seed pods on any plants, either cultivated or wild, and no data exists for germination of *C. verticillata* seed, to my knowledge.

White wicky, *Kalmia cuneata,* is one of the rarest shrubs of the U.S. East Coast. It is found only in eight counties in the Carolinas where it inhabits sand plains and pocosins. A rhizomatous shrub, it grows to 5 ft and features a creamy-white flower with an inner red band. It blooms later than *K. latifolia,* in July rather than June, and is unique among kalmias in that it is deciduous and shows a maroon fall color. We now have an 8-year old plant that has survived sub-zero temperatures.

Cuttings were taken in July from this specimen and stuck under an intermittent mist system. Treatments were 8000 ppm IBA powder and control; and media of peat and perlite (1:1, v/v), and sand and perlite (1:1, v/v). In the peat mix, IBA-treated cuttings rooted 60% with control rooting 80%; while in the sand mix the IBA-treated rooted 90% and controls rooted 0%.

Seeds germinated without pretreatment, with seedlings appearing after one month. However, Richard Jaynes states in his definitive book, "The Laurel Book" that seed receiving a cold stratification of one to four months germinates much better than those receiving no cold treatment.

This plant is probably useful for planting in sandy soils, rock gardens, and small scale landscapes.

Cladrastis kentuckea, or *C. lutea* as it was formerly known, is a large tree with the common name, yellow wood. It ranges from central Indiana to southern Alabama and from eastern Kentucky out to Oklahoma, but is rare and scattered throughout. In cultivation, yellow wood can reach heights of 60 ft, with a spread generally wider than its height. I have seen specimens with a trunk circumference of 14 ft.

It is an all-seasons ornamental. Long hanging panicles of sweetly fragrant white flowers appear in mid-June. In general, the tree has a good floral display every other, or even every third year. Foliage is compound, usually seven large leaflets per leaf. Fall color ranges from clear yellow to a soft orange. Winter interest is created by its grey beech-like bark and striking habit.

Propagation by seed is quite simple. Like many woody legumes, once the seed is removed from the pod, the hard, impermeable seed coat must be scarified. The easiest method is simply to put the seeds in a container, add boiling water, and allow to cool. Seed must then receive a cold stratification period of three months prior to sowing.

The existence of a pink-flowered form makes vegetative propagation desirable. Unfortunately, *C. kentuckea* is difficult to propagate by cuttings. This summer I attempted to root cuttings from a 60-year-old tree of the species under mist. An experiment was set up with two media, sand and perlite (1:1, v/v) and pumice mix Treatments were 8000 ppm IBA powder, a 6000 ppm K-IBA saturated toothpick inserted longitudinally at base as described for the magnolia, and control in the sand mix. Only the toothpick treatment produced any rooting, at 10%. However, in the pumice mix, the control and IBA powder treatment rooted 10%, while the toothpick treatment rooted 70%.

Grafting is also possible and our records show success in grafting the pink-flowered cultivar, 'Rosea' onto the species. *Cladrastis kentuckea* 'Rosea' was first described in 1961, registered in 1963, and has been sporadically propagated at the Arnold Arboretum. It is a plant we hope to have for distribution in the near future.

The plumleaf azalea, *Rhododendron prunifolium*, was first introduced to horticulture in 1918 by the Arnold Arboretum. It is found only in wooded ravines in a limited area along the southern Georgia-Alabama border. I have seen it growing as an understory plant on a steep slope whose soil was quite heavy.

Its value to horticulture is primarily its lateness of bloom. In Boston, the reddish-orange blooms usually start in late July and continue well into August. This late flowering makes it a valuable partner for hybridizing and this has been proven by the late Ed Mezitt, whose fine hybrids were shown last year by Wayne Mezitt. The plumleaf azalea, despite its southerly distribution, shows surprising hardiness, having been hardy in Boston for decades, and having been rated as hardy to −25°F by the State Arboretum of Minnesota.

From cuttings taken from an old plant in early July, I was able to get good rooting percentages. Both the pumice mix and sand mix (see *I. collina*) were used with a hormone treatment of 8000 ppm IBA powder. The pumice mix showed 80% rooting for control, and 87% for hormone treatment. The sand mix showed 80% rooting for control, and 93% for hormone treatment. Rooting quality was a bit better in the pumice mix with 70% of the rooted cuttings rated excellent, versus 55% for the sand mix.

Seed germination is quite simple provided sound seed is obtained. I have had good seed germination from direct sowing onto sphagnum moss, although germination would probably be more uniform with a short, cold stratification. Because of its late bloom, *R. prunifolium* often does not have enough time to set good seed in Boston. One way around this might be to containerize some plants which could be brought into a greenhouse to develop further.

Franklinia alatamaha, a member of the camellia family, is this country's most famous rare woody species. Once native to the Alatamaha River drainage area Georgia, it has been extinct in the wild for almost two centuries.

At the Arnold Arboretum we have a number of mature specimens measuring about 18 ft high and equally broad. Habit is loose and upwardly arching. Franklinia's outstanding ornamental attributes are its gorgeous white blossoms and its burgundy fall color. As the species flowers in autumn, usually in September and October, it is possible to have blooms and fall color coinciding.

Under mist, cuttings taken in early August rooted quite easily at 100% when treated with 8000 ppm IBA powder and placed in pumice mix. Similar results were obtained with a 6000 ppm K-IBA dip in the same medium. In a sand and perlite medium, 8000 ppm IBA powder rooted 100 percent although quality was a bit less than the pumice lots as only 80% showed excellent roots vs. 100% excellent for pumice. A control in this medium rooted 80%.

Franklinia seed differs from *Stewartia pseudocamellia,* another member of the Theaceae, in that it does not have a double dormancy and seed germinates well after a 3 month cold stratification period.

NEW PLANT FORUM

JACK ALEXANDER AND GARY KOLLER, MODERATORS

SUSAN NOLDE: *Juniperus conferta* 'Silver Mist' has been in the Japanese nursery trade for years. It was named and registered by Brookside Gardens in 1983 after no valid cultivar name was found in the Japanese literature. We purchased this plant from a large exporter in the Angyo Nsy area of Japan.

'Silver Mist' is similar to *J. conferta* 'Blue Pacific', however, it has distinctly grayer foliage. Additionally the needles are shorter which gives the plant a thicker and denser appearance. It is more compact than the species. This clone has been around for quite a while. The U.S. National Arboretum has it in the Gotelli collection and some nurserymen may have this plant under another name.

Monrovia Nursery has shown a great deal of interest in this plant. We have distributed it to them and it should be showing up in the trade under this name soon. It is also being tested by Weyerhauser Research Program so Hines Nursery may be carrying it soon as well. Additionally we have also distributed it to selected evaluators around the country, including Eisely Nursery in Oregon and the North Carolina State University Arboretum, which has made it available to nurseries in North Carolina. Cuttings root 80% with an 0.4% IBA-talc treatment.

GUSTAV MEHLQUIST: *Rhododendron* 'April Dawn' is a single-flowered selection from a cross between *R. dauricum* var. *album* and *R. carolinianum* var. *album*.

Height: 4 to 5 ft in 10 years.
Blooming time in Connecticut: April, about five days later than R. 'P.J.M'.
Flower color: pale to medium pink, depending on temperature.
Flowering habit: similar to R. 'P.J.M'.
Number of petals: five.
Foliage color: somewhat lighter than R. 'P.J.M'.

Rhododendron 'April Rose' is a double-flowered, rose-colored evergreen selection from crosses involving *R. dauricum*, *R. dauricum* var. *album*, *R. carolinianum*, and *R. mucronulatum* 'Cornell Pink'.

Height: 3 to 4 feet in 10 years.
Blooming time in Connecticut: April.
Flower color: rose.
Flowering habit: similar to R. 'P.J.M.'.
Number of petals: 12 to 15.
Foliage color: deep red throughout the year.

Rhododendron 'April Gem' is a double-flowered, pure white evergreen selection from crosses involving *R. dauricum*, *R. dauricum* var. *album*, *R. carolinianum* var. *album* and *R. mucronulatum* 'Cornell Pink'.

Height: 3 to 4 ft. in 10 years.
Blooming time in Connecticut: April.
Flower color: pure white.
Flowering habit: similar to R. 'P.J.M.'.
Number of petals: 12 to 15.
Foliage color: green, leaves that drop in fall turn bright yellow.

Rhododendron 'April White' is a semidouble, pure white evergreen selection from crosses involving *R. dauricum*, *R. dauricum* var. *album*, *R. carolinianum* var. *album*, and *R. mucronulatum* 'Cornell Pink'.

Height: 3 to 4 ft in 10 years.
Blooming time in Connecticut: April.
Flower color: pure white.

Flowering habit: similar to *R.* 'P.J.M.'.
Number of petals: 10 to 15.
Foliage color: green, leaves that drop in the fall turn bright yellow.

JIM ZAMPINI: *Malus* 'Molten Lava' is a new weeping crabapple with red buds opening into masses of white flowers in the spring. Cascades of brilliant red fruit flow like lava from the pendulous branches throughout the fall season. 'Molten Lava' will reach a height of 15 ft and have a spread of 12 to 15 ft. The foliage is green. This cultivar is the strongest grower of all weeping white *Malus* and is free of scab. I recommend the use of Gro-Straights and metal stakes for the production of superior trees. It is hardy to Zone 4.

Malus 'Madonna' P.A.R. forms a compact upright head (height to 18 ft and spread of 10 ft) that makes it ideal for street tree or landscape use. The large (2½ to 3 in.), double, fragrant white flowers open slowly. It is among the first crabapples to show color in the spring and the last to go out of bloom. Clusters of golden fruit with a blush of red follow the flowers. During production little or no pruning is required, tree and shrub forms are easily produced, and it is disease tolerant. It is hardy to Zone 4.

Tilia cordata 'Corinthian' grows as a compact pyramid with a potential height of 45 ft and spread of 15 ft. The formal shape of this tree is created by evenly-spaced limbs around a straight central leader. Dense branching combines with thick, lustrous dark-green foliage to make a shining pyramid in the summer. The leaves are smaller, thicker, and glossier than the species. The flowers, which are ivory and fragrant, are followed by tan fruit about ¼ in. in diameter. 'Corinthian' is dormant one week longer than other cultivars. Growth is slow compared to other cultivars the first year but the growth catches up the second and third year. It is hardy to Zone 3. Growing suggestions for superior trees include the use of Gro-Straights in the spring and metal stakes.

Elaeagnus umbellata 'Titan' P.A.F. is a plant that can be used as an easily con-*trolled hedge or screen. 'Titan' grows to 12 ft and has a width of 5 ft. Its dense,* uniquely upright branching gives it all-seasons beauty starting in the spring when it is covered in a mass of soft, golden sweet-scented flowers. During the growing season, its leaves are a rich olive green. With the slightest breeze, each leaf dances a silver reflection. In the fall its bold red fruit attracts songbirds. Hardy to Zone 4.

JACK ALEXANDER: *Leycesteria formosa,* the Himalaya honeysuckle, is a member of the Caprifoliaceae or honeysuckle family. It has been cultivated in the West since 1824. Its native range extends from northwestern India through the Himalayas to southeastern Yunnan and northeast to Szechuan and Tibet. Future selections from some of the colder regions of the range may serve to extend its use as a garden plant. It is not very hardy, but can be successfully grown as far north as USDA Zone 6 by treating it as an herbaceous perennial and cutting back each seasons growth to near ground level. The leaves of *Leycesteria formosa* are bright green and opposite. Stems reach heights of 4 to 5 ft in a season, are hollow, bluish green, and arching.

The funnel shaped white or pinkish flowers are produced over a period of several weeks in mid-summer and are on the current season's growth near the ends of the arching branches. They are in terminal or axillary spikes that include very attractive ½ to 1½ in. long purple bracts. The fruits are many-seeded, shiny, reddish-purple berries and borne among the persistent, purple bracts. It is this combination of fruits and bracts that are the plants most attractive feature and on a sunny October day all passers-by will stop to admire them. The fruits are said to be edible, but having tried them, I do not recommend them. Birds are reportedly very fond of them.

In the North, it is necessary to transplant the Himalaya honeysuckle in the spring, so that plants will have a growing season to become established before winter. *Leycesteria formosa* will tolerate light shade, but colors best in sunny locations. Seeds, which are abundantly produced, germinate without pre-treatment. Seedling growth is rapid and lush.

CLARENCE FALSTAD: The herbaceous perennials, *Hosta sieboldiana* cvs. Northern Halo and Northern Lights, are both sports of the popular blue-gray leafy hosta, *H. sieboldiana* 'Elegans'. These plants were developed and registered by Walters Gardens, Inc., Zeeland, Michigan.

Hosta sieboldiana 'Elegans' in maturity has large, heavily-textured, corrugated, blue-gray leaves mounding out 36 to 40 in. above a densely rhizomatous base. The near white flowers are closely clustered on a spike showing just above the foliage.

Hosta sieboldiana 'Northern Halo' is identical to *H. sieboldiana* 'Elegans' except that it has a creamy-white margin surrounding the leaf.

Hosta sieboldiana 'Northern Lights' has a creamy-white center with some light green ribboning between the blue-gray margin and the center. This cultivar is noticeably slower growing than the parent due to reduced chlorophyll.

Hosta 'Moon Glow' was discovered and registered by Ken Anderson. This selection develops a rich, toasted gold leaf by mid-summer that is also variegated with a creamy-white border. A mature plant gets 18 to 24 in. tall and the leaves become slightly corrugated. The flowers are near white.

KRIS BACHTELL: One type of vernal witchhazel that deserves a closer look by propagators and nurserymen is *Hamamalis vernalis* f. *carnea*, the red-flowering vernal witchhazel. According to Steyermark in his *Flora of Missouri*, *H. vernalis* f. *carnea* naturally occurs sporadically in only two adjacent counties in southeastern Missouri. Besides the unusual flower color, this plant often possesses exceptionally beautiful fall color. The colors range from orange-red to deep maroon and can often resemble the fall color of *Fothergilla gardenii*. The fall color of individual plants can vary and selections should be made from seedling-grown plants for good, consistent autumn coloration. I know of two nurserymen that are currently working on such a project. A few cultivar selections of *H. vernalis* f. *carnea* have already been made. One hard-to-locate selection named 'Sandra' was selected by Hillier Nursery in 1962. Hillier's *Manual of Trees and Shrubs* states that, "in autumn the whole bush ignites into orange, scarlet and red."

Hamamelis vernalis f. *carnea* can be rooted by cuttings quite successfully. In fact, *H. vernalis* is reported to be the easiest witchhazel to root. For seed propagation, collect fruits before the seed has been expelled from the capsule, and sow immediately. Seeds treated this way will germinate in fairly good percentages the first spring. Germination will also likely occur the second year.

Juniperus communis 'Repanda' is an attractive and useful ground cover juniper that merits greater use. 'Repanda' is an old selection from Ireland made before 1934. Its sex is undetermined. Hasselkus and Schneider in their ground cover juniper evaluation, *The Best and Worst Ground Cover Junipers for Landscapes in the Midwest*, published in the American Nurseryman, July 15, 1983, rated this plant to be the best selection of *Juniperus communis* they observed.

Mature plants of 'Repanda' reach a height of only 15 in. and form fairly regular circles. The needled foliage is medium-green during the growing season and turns yellowish green in winter. The foliage color holds well in winter while other selections from this species turn brown. Although the foliage is coarsely textured, the twigs are very supple and flexible, and soft to the touch. The foliage densely covers slightly ascending branches that nod at their tips. Juniper or Phomopsis blight (*Phomopsis juniperovora*), a disease that is particularly destructive to many ground cover junipers in the Midwest, has not been reported to affect this plant.

'Repanda' is easy to propagate successfully from cuttings. Cuttings taken in winter and treated with 5000 ppm IBA quick-dip have rooted in high percentages.

JOHN WALTERS: *Hibiscus* 'Anne Arundel' (PP5209) is an introduction by Richard Darby, formerly of College Park, Maryland, and now of Iowa City, Iowa. Mr. Darby has done some excellent work with the hardy hibiscus including breeding the outstanding cultivars, *H.* 'Lady Baltimore' (PP4271), and *H.* 'Lord Baltimore'. Anne Arundel is currently under an exclusive selling arrangement with Wayside Gardens of Hodges, South Carolina. It is scheduled to become available to the general nursery trade in the fall of 1989 and spring of 1990.

This exceptional hibiscus can best be described as a glorious pink. The flowers are 9 in. across and the height is 4 to 5 ft. The bloom period begins in Michigan in early July and continues into October. This is an exceptionally long bloom period for this type of hibiscus. The flowers extend appropriately beyond the foliage giving them a full color effect. Anne Arundel is known to be hardy to Zone 5 without mulching. The leaves are moderately abundant, finely cut, and decorative. The color of the leaves is medium green and palmately lobed. The growth is vigorous. It is a hardy herbaceous perennial with bushy annual growth from the root stock.

This is a normal hibiscus in that dormancy is broken very late in the season with very little show even with foliage until late spring. The very long blooming period from early summer until well into fall makes this hibiscus a very desirable plant for a summer flowering hedge or border, or grouped to form a landscape focal point.

Echinacea purpurea 'Alba' is a seed-grown *Echinacea* with good creamy-white flowers and showing only slight variability when seed-grown. The cone is coppery-brown with the white petals displayed quite flat this allows the flowers to be displayed at their best. Flowering begins in late June in Michigan and continues well into September. Flower performance peaks during July and August with a continual display of white flowers that makes this plant an exceptional, long-blooming perennial. Height is about 24 to 26 in. with blooms approximately 4 in. in diameter. The dark green, heavily-textured foliage arises from a single root.

Our observations over three years indicate *E. purpurea* 'Alba' to be a long lived perennial and hardy without winter protection to at least Zone 5. In general, *E. purpurea* is described as being hardy throughout the continental United States. It is described as being strong, drought tolerant, and a low maintenance perennial. Other white *Echinacea* cultivars currently being offered include: 'White Lustre', 'White King', 'White Prince', 'White Swan', 'Talent White', and possibly others. *Echinacea purpurea* 'Alba' can play a valuable role in the perennial landscape, and also in naturalized plantings.

BILL THOMAS: *Chrysanthemum pacificum* is a garden perennial, ground cover, or pot plant grown primarily for its foliage. The leaves are white-edged and bright white tomentose underneath. Small yellow blossoms appear in early November and stay attractive for about 3 weeks. A Japanese native that spreads quickly to 3 ft and a height of 15 in., it needs no staking or pinching. It is a full sun plant that tolerates hot, dry conditions. Perfectly hardy in USDA Zone 7, it probably will grow much further north.

Stem cuttings root any time of the year and Longwood Gardens will provide cuttings to get nurseries started growing it. Propagation is also possible by division.

Pennisetum setaceum 'Burgundy Giant' is a coarse-textured ornamental grass with purple leaves and large purplish flower clusters. A rapidly growing annual in most parts of the country, it is actually a USDA Zone 10 perennial. Burgundy giant pennisetum propagates very quickly when stem cuttings are taken between April and September. It roots within 10 days in sand under mist, and can reach 7 ft in height with a 3-ft width in one growing season. Individual stock plants easily over-winter indoors. Marie Selby Botanic Garden and Longwood Gardens are registering the cultivar name and Longwood will have cuttings available by the summer of 1988.

Sorbus rufoferruginea is a healthy and attractive, Japanese mountain ash that thrives in hot summers which usually kill other members of the genus. Our 20-year-old plants are 20 ft tall and wide, with a round-headed form, and free of scab and fireblight. This tree is spectacular the entire month of October with wine-red leaves and contrasting orange fruit clusters. The fruits remain showy well into December. Longwood Gardens will provide scions and seeds. Seeds need a 2 to 3-month cold stratification period.

ROB NICHOLSON: *Betula apoiensis*, the dwarf Apoi birch, is a Japanese species that is restricted in its range to one mountain. Mount Apoi is situated on the south coast of Hokkaido, Japan's northernmost island. The mountain is a few miles from the sea, reaches an altitude of 900 m, yet has an alpine zone with a number of endemic species. This birch is found between 600 and 800 m, usually growing in gravelly places and rocky crevices. Species found with it are *B. ermanii*, *Alnus maximowiczii*, *Pinus pumila*, *Rhododendron dauricum*, and *Potentilla fruticosa*.

In 1977 Drs. Richard Weaver and Steven Spongberg collected seed on this mountain for the Arnold Arboretum and the dwarf Apoi birch was among their collections. The plants they collected from were only 2 ft high and we now have a stand of ten year old plants grown from this seed. All are under 3 ft high, some being multi-stemmed and some show a single leader. The white bark of this birch coupled with its small stature make it a fine species for small scale landscapes and rock gardens.

Propagation by seed is fairly straightforward; give the seed a short stratification period of 2 or 3 months before sowing to ensure uniform germination.

PETER DEL TREDICI: *Pinus nigra* 'Arnold Sentinel' continues a long tradition of introducing new plants by the Arnold Arboretum. This fastigiate clone was selected from a group of seedlings that were raised in 1970 from seeds collected in western Turkey by Turkish entomologist; Dr. Abdulgafur Acatay. The seeds came from a wild population of *Pinus nigra* that naturally showed the upright or pyramidal habit. Dr. Acatay discovered the stand which covered about 110 acres near Mt. Uludag, in 1955, and in 1968 he described it as *Pinus nigra* var. *pyramidata* (Mitt. Deuts. Dent. Gesell. 63, Jahrbuck 1967/68: 54–54).

In 1970 Dr. Acatay sent seeds from this stand to nurseries and botanic gardens throughout the world including the U.S. National Arboretum, who forwarded half of their share to the Arnold Arboretum, where they were accessioned under the number 502-70. Numerous seedlings were raised at the Dana Greenhouses by the former plant propagator, A. J. Fordham, and seven of the most upright were planted out. The seedling selected as 'Arnold Sentinel' is now 16 ft high but only 4 ft wide. It keeps a good dark-green color throughout the winter, and has a dense, full habit. Possessing the same salt tolerance of the species, this new fastigiate clone can offer a touch of variation to the often tedious rows of *Pinus nigra* that adorn so many of our highways and industrial complexes.

During January, 1987, the branches of the tree were badly splayed out by a series of ice and snow storms. The damage was severe enough to cause a delay in our scheduled introduction for a year to see if the plant could recover from the trauma. Today I am happy to report that the tree has fully recovered its upright habit. *Pinus nigra* 'Arnold Sentinel' has the backbone to stand up to the rigorous environmental conditions it would have to face in many of the most demanding landscape sites.

GARY KOLLER: *Schizophragma hydrangeoides*, Japanese hydrangea vine, is a little known Japanese plant which suffers lack of landscape use as a result of being compared, unfavorably, with climbing hydrangea (*Hydrangea anomala* subsp. *petiolaris*). The two plants are similar in that they are native to the woodlands of Japan where they climb trees, attaching themselves to the trunk with rootlike holdfasts. They both grow naturally in a shaded woodland environment and clamber to the tops of the tree canopy where they spread out gaining the advantage of an exposure of full sun which encourages optimum flowering. They both prefer a moist but well-drained soil. Both vines are hardy to approximately −25°F.

Japanese hydrangea vine differs from climbing hydrangea in the following ways. In Boston, *Schizophragma* flowers in July after climbing hydrangea finishes its bloom sequence, thereby providing landscape designers with the option of extending bloom. Using both species of vines in a landscape allows a designer to extend floral interest over a longer season. By selecting one or the other the designer can choose when the floral presentation will be most effective in relation to the total landscape scene. Japanese hydrangea vine bears showy creamy white bracts which remain in good condition for 4 to 6 weeks depending on the exposure and ambient air temperatures of the season. However, as the bracts begin to age they fade to a straw-brown color and remain visually effective for a period of 2 to 3 months. At the Arnold Arboretum they are showy till early October when they tend to recede into the landscape picture as a result of competition with more colorful autumn foliage. Since both species of vines flower in light to moderate shade they are excellent choices where lack of sun might be problematic from a plant selection standpoint.

Japanese hydrangea vine clings to wood, masonry, or stone much the same as climbing hydrangea but it bears shorter horizontal branches resulting in less bushiness. *Schizophragma* tends to contour itself more closely to the surface upon which it climbs.

Autumn color is different! The Japanese hydrangea vine produces a pale yellow to amber autumn color while climbing hydrangea leaves fall away still basically green color.

Oneestablish growth after transplanting and can take 4 to 6 years to resume normal shoot elongation. Japanese hydrangea vine, on the other hand, attaches itself to a wall and begins rapid upward growth within the second or third growing season. This faster growth allows quicker coverage and greater customer satisfaction.

Two existing new additions to the world of Japanese hydrangea vines are a pink-flowered clone (*Schizophragma hydrangeoides* 'Roseum') introduced by the Arnold Arboretum from Europe and which will be for sale at the September, 1988 Rare Plant Auction of the Arnold Arboretum. A new clone recently named 'Moonlight' was introduced by Brookside Gardens in Wheaton, Maryland. 'Moonlight' bears leaves weakly marked with a silvery color or sheen while the veins are dark green producing a color combination which appears as though moonlight shines on the foliage. 'Moonlight' roots more easily and over a wider seasonal range than cuttings taken from the typical species.

Seeds require one month of cold stratification to insure optimum germination. Seeds are small, dust-like and light brown in color. The plant can be easily reproduced vegetatively if cuttings are taken from soft new season growth before flowering.

NANCY VERMEULEN: *Pinus thunbergiana* 'Mini-mounds', mini-mounds Japanese black pine, was almost named 'Many-mounds' and then 'Many Mini-mounds'. It's ultimate mature habit is not yet certain. Our original plant is now 23 years old. It has been under close evaluation since it was purchased from Princeton Nurseries in 1975 as an 11-year old specimen. The name aptly describes the plant which is low and dense with merging mounds of medium-green foliage. The 3½ to 4 in. needles are closely spaced along short shoot growths, mostly 3 to 5 in. with occasional shoots to 8 in. These are bunched attractively so as to form larger mounds comprised of other mini-mounds. Our original plant measures 7 by 9 ft wide and 2 to 4 ft high. It has a trunk caliper of 4½ in. Spring "candles" on 'Mini-mounds' are extremely attractive. In its early years the plant grows somewhat awkwardly, like a gangly teenager. But what a handsome mature plant it makes!

SIDNEY WAXMAN: *Larix laricina* "Newport #7" and "Newport #9". Both seedlings, Newport #7 and Newport #9 were obtained from a witches'-broom found in Newport, Maine in 1977. They were selected from a group of 95 seedlings. Both selections are dwarf and have very short branches. The needles are approximately ½ in. long. The outstanding characteristics of each cultivar is the vibrant light bluish-green foliage that develops each spring. In the fall the needles turn a deep tan. In winter they look like a small mass of dense chocolate-brown twigs. Newport # 7 is a mounded dwarf that has grown about 2 ft wide and one foot high after 7 years. Newport # 9 differs from # 7 in that it has more strongly developed lateral branches. It is slightly irregular in form and not as tall as # 7.

Both selections can easily be propagated by cuttings, but because they do not do well in dry soils, I would recommend that they should be grafted onto a larch rootstock that is more tolerant of soils that are drier than those in which the American larch is commonly found. Grafting onto Japanese or European larch is acceptable.

R. WAYNE MEZITT: *Rhododendron* 'Weston's Pink Diamond' was selected as the outstanding plant from a 1964 cross (our # 201) performed by Edmund V. Mezitt (*R.* P.J.M. × *R. mucronulatum* 'Cornell Pink') and introduced in 1983 to commemorate our nursery's 50th anniversary. It is a lepidote and has tested flower bud hardy at the University of Minnesota Landscape Arboretum to −18°F.

Its best attribute is the heavy flowering in late April in Hopkinton, MA. Flowers are clear-pink and fully double. The plant is multistemmed, wide, upright, and retains less than 50% of its foliage in winter. Leaves are bright green in summer, becoming red, orange, and yellow in fall, or mahogany in winter if they are evergreen. The original plant is now about 5 ft tall and 3 ft wide; anticipated mature size is 8 ft high and 5 ft wide.

Rhododendron 'Milestone' is a compact growing lepidote, originally called 'Marathon' by us because its April bloom often coincides with The Boston Marathon that begins in Hopkinton on about April 19th. (The name was changed because another rhododendron was already registered as 'Marathon'). Its current registered name is appropriate because our nursery is located at the one-mile point of the Boston Marathon. The flower bud hardiness of 'Milestone' has been tested and found to be −13°F by the University of Minnesota Landscape Arboretum.

This next plant is a selection from a 1972 cross performed by Edmund V. Mezitt. It is a self-pollinated seedling of *R.* 'Mindaura': *R. minus* 'Compactum' (a form from Wyman's Framingham Nurseries) × *R. dauricum* var. *sempervirens* (Probably the same parent used for the original *R.* P.J.M. cross in 1938). I think it is our cross # 913. Its bloom begins with dark pink buds which open to just-as-dark flowers that retain their color intensity throughout the entire bloom period; it appears almost red from a distance. Foliage is quite small, dark green in summer and red, yellow and orange in autumn. Less than 50% of the foliage is retained in winter and it has a burgundy-mahogany color. Flower buds are prominent in winter. As with most plants in the *R. dauricum* group, this one performs best when planted in full sun and well-drained, rich, acid soil.

STRUCTURES USED IN AUSTRALIA FOR PLANT PROPAGATION

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INTRODUCTION

The size and climatic diversity of Australia are frequently misunderstood. A comparison of size shows that Australia has a land mass of 2.9 million square miles and the continental United States has 3 million square miles. The two countries are comparable in size.

A study of the latitudes of the major cities of Australia will help to understand the climatic diversity. A comparison with northern hemisphere cities on similar latitudes is given in Table 1.

Table 1. A comparison of latitudes of southern and northern hemisphere cities.

Latitude	Temperature	Southern Hemisphere	Northern Hemisphere
12°	(24–32°C)	Darwin, Northern Territory	Grenada
17°	(20–29°C)	Cairns, Queensland	Kingston, Jamaica
23°	(18–29°C)	Rockhampton, Queensland	Havana, Cuba
27°	(16–26°C)	Brisbane, Queensland	Tampa, Florida
32°	(13–23°C)	Perth, Western Australia	Savannah, Georgia
34°	(14–22°C)	Sydney, N.S.W.	Atlanta, Georgia
37°	(10–20°C)	Melbourne, Victoria	Norfolk, Virginia
43°	(8–17°C)	Hobart, Tasmamia	Detroit, Michigan

*Temperatures supplied by the Australian Bureau of Meteorology.

Most major Australian cities are located on the coasts, which means that the maritime influence has a major effect on temperatures and prevents the extremes experienced inland.

The subtropical areas of Queensland and Northern New South Wales are the major production centers of foliage plants in Australia. Frost incidence is not a serious production problem, although some winter heating is necessary. Rainfall occurs primarily in summer. Light intensity is not a limiting factor to winter growth.

Southern New South Wales, Victoria, and South Australia are the major centers for temperate plant production. The area has relatively hot, dry summers and cool, wet winters. The low winter angle of elevation of the sun is a limiting factor to growth in southern areas in winter.

The area around Perth in Western Australia has a very well-developed nursery industry, producing most types of stock. However, the small domestic population of Western Australia and its isolation create natural restrictions on the growth of the industry in that state.

By U.S. nursery standards the average Australian nursery is small and relatively unsophisticated. Capital investment is usually rather small and the range of production facilities is often a limiting factor in production.

TREMENDOUS DIVERSITY OF CLIMATE

Design of greenhouse structures. The history of greenhouse design in Australia parallels design styles of Britain and Holland. Glasshouses have been constructed using design styles that have evolved for cold winter climates with low winter light intensity. This is not the ideal design for Australia so in the last 10 years a number of different design styles more appropriate to the climate have been introduced. This has led to the establishment of a thriving local greenhouse construction industry.

The major environmental factors of light, temperature, humidity, and carbon dioxide must be taken into consideration in the design of a greenhouse.

Light. For propagation purposes light intensity must be closely controlled. Over most of Australia the natural light intensity is more than adequate, even in the middle of winter. For cutting propagation it is usually necessary to reduce the natural light intensity, either by shading or by the use of light-reducing greenhouse covers.

Horticultural glass is rarely used as a greenhouse covering material. The cost of conventional glasshouses is now so high that few nurserymen will consider their construction. Rigid plastic covering materials have been widely used. These rigid materials fall into two groups: 1) fiberglass sheeting (F.R.P.), and 2) polycarbonate structured sheets (P.C.S.S.).

Both of these products can be obtained as clear sheets or with white or tinted pigments incorporated for light reduction. In areas of high light intensity it has been common practice to select tinted sheets for propagation use. However, it appears that quality control standards within the plastics industry are very poor. Many nurseries have been supplied with rigid plastic sheeting of both types that degrade at an alarming rate.

As a result, the trend in the use of these materials is now towards clear-grade sheeting, which lasts considerably longer than tinted grades. For shading purposes shadecloth, paint-based shading, and internal screens are all commonly used. Although light intensity must be reduced, transmission through the tinted sheets may drop to 12 percent in three years, which, of course, is much too low.

The high natural light intensity has enabled greenhouse designers to change the basic shape of greenhouses. The high-pitch roof of the English glasshouse has been replaced by a much lower roof pitch in some conventional designs and by the semicircular roof profile in others.

The increasing trend towards the use of plastic film covers has enabled design changes to be made. A wide range of high and low density polyethylene film products are in use as greenhouse covers. Products such as Solarweave, Agphane 101, Infrasol 266, Thermofilm IR, and Ag-Tuff are available. In the majority of installations a single layer of film is used. However, some greenhouse manufacturers are now promoting the advantages of double-layer plastic covers in the control of the greenhouse environment so the use of double-layer polyethylene is now increasing (Figure 1). Improved film fastening techniques now make double-layer plastic covers safer to use.

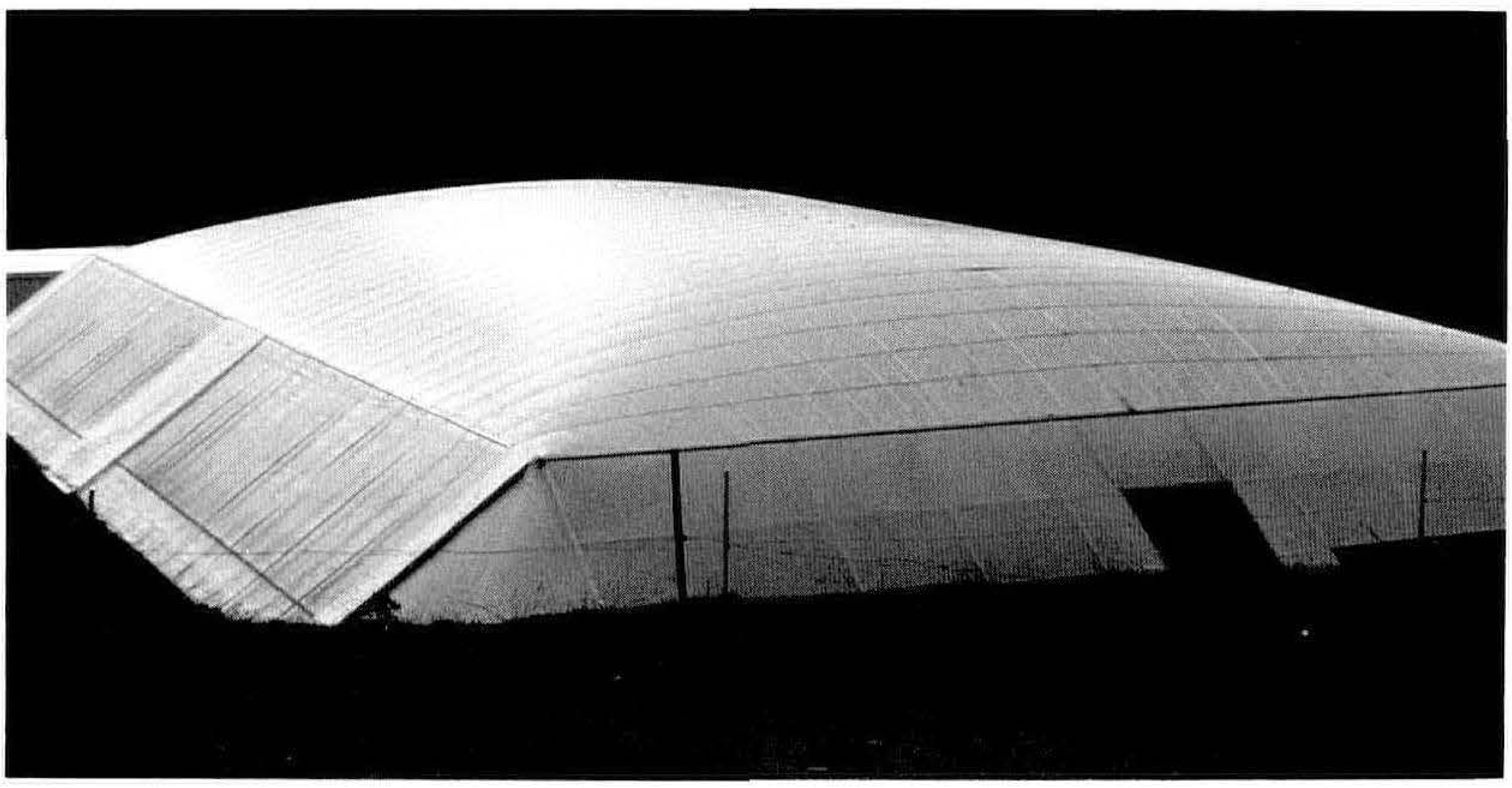

Figure 1. Inflated double-layer polyethylene covering is becoming popular in Australia.

The high ultraviolet light conditions of the Australia's East Coast cause rapid degradation of most plastic films. UV stabilized low density polyethylene film (L.D.P.E.) will only last for 18 months in the Brisbane region, whereas nurseries in Melbourne report a life expectancy of three years or more. Solarweave plastic, a toughened L.D.P.E. film has a life expectancy of four years in Brisbane.

Temperature management. Ventilation of greenhouses is an area of great importance. With single span structures it is still possible to rely on natural ventilation incorporated as part of the design. Hinged side walls that open to expose a large surface area of ventilator space and drop-down side walls are two widely used less conventional designs for natural ventilation.

In multispan structures natural ventilation alone is inadequate to cool the structures uniformly. Problems with natural ventilation

Figure 2. Roof-vented poly-covered quonset structure.

also occur in propagation structures where a high-humidity environment is maintained. In these situations a variety of fan ventilation systems are used. Double poly film is good for heat conservation but makes ventilation difficult. However, ways to ventilate through the roof are now being developed, as shown in Figure 2.

The use of perforated plastic ducts for the distribution of cool air uniformly through the greenhouse is common. The ducts may be connected directly to an inlet fan so that air at ambient outside air temperature is distributed through the greenhouse. Alternatively, the ducts may be connected to an evaporative cooling unit so that there is some actual cooling of the outside air prior to circulation. A large percentage of the nursery industry is located on the narrow coastal strip of eastern Australia. This region has a high summer relative humidity, which makes evaporative cooling of dubious value.

A further advantage of the use of plastic ducts is that they can be used for heating purposes in winter if required. Few nurseries north of Brisbane have the need to provide winter heating, but from Brisbane south there is a need for some winter heat. However, the actual heat requirement may be quite low and the duration of heating may only be for three months of the year.

The traditional practice of space heating is now losing favor so greater use is being made of root-zone warming, as shown in Figures 3 and 4. Both floor and bench-incorporated heating systems are

Figure 3. Bottom heat in the floor.

Figure 4. Heat lines are laid in a sand bed then covered with matting.

widely used. Mineral-insulated copper core cables (M.I.C.C.) are commonly used in both floor and bench systems. However, in the last few years warm-water heating systems have become popular.

Work carried out by Brian Hese of the South-East Queensland Electricity Board indicates that in a floor heating system with warm water circulated through 16mm polyethylene pipe, the water temperature need only be 40 to 50°C to maintain a pot-media temperature of 18°C, assuming an outside temperature of 7°C. This provides the opportunity for innovative approaches to reduce heating costs.

The use of Night Rate (Off-Peak) Tariff electric power for greenhouse heating is now widespread. This provides the ability to heat the greenhouse between 2300 and 0700 hours, the period when most heating is required. If heating is needed at other times, it will be necessary to install an insulated hot-water storage tank.

In the design of a greenhouse heating system it is important that excessive heat loss through the structure be avoided to minimize heating costs. Many Australian nurserymen have installed internal thermal screens as an additional measure to minimize heat input. Double-layer plastic film covers also play a major part in reducing heating costs. Work carried out by the Commonwealth Scientific and Industrial Research Organization (C.S.I.R.O.) at Griffith, New South Wales, indicates a 40% savings in energy costs with a double-layer plastic cover. In the Darwin area a shade house gives enough protection for foliage plants.

Other factors considered important in the minimization of heating requirements are:

1. Redesign of greenhouses to reduce the surface area of the structure.

2. Provision of windbreaks.

3. Correct placement and calibration of temperature-sensing equipment.

4. Development of new covering materials with improved thermal performance.

Solar heating. The natural climate of most of Australia lends itself to the development of greenhouse solar heating systems. The high winter sunshine hours provide the opportunity for large-scale solar heating designs.

Two approaches to solar heating are in use in Australia. The C.S.I.R.O. Low Energy Greenhouse Project involved the adaptation of a greenhouse to enable daytime solar heat gains to be collected and stored in an adjacent rockpile. When heating of the greenhouse is required, the collection cycle is reversed; and warm air from the rockpile is returned to the greenhouse. The rockpile is stored in a tall insulated chamber constructed on the end of the greenhouse structure (Figure 5, above).

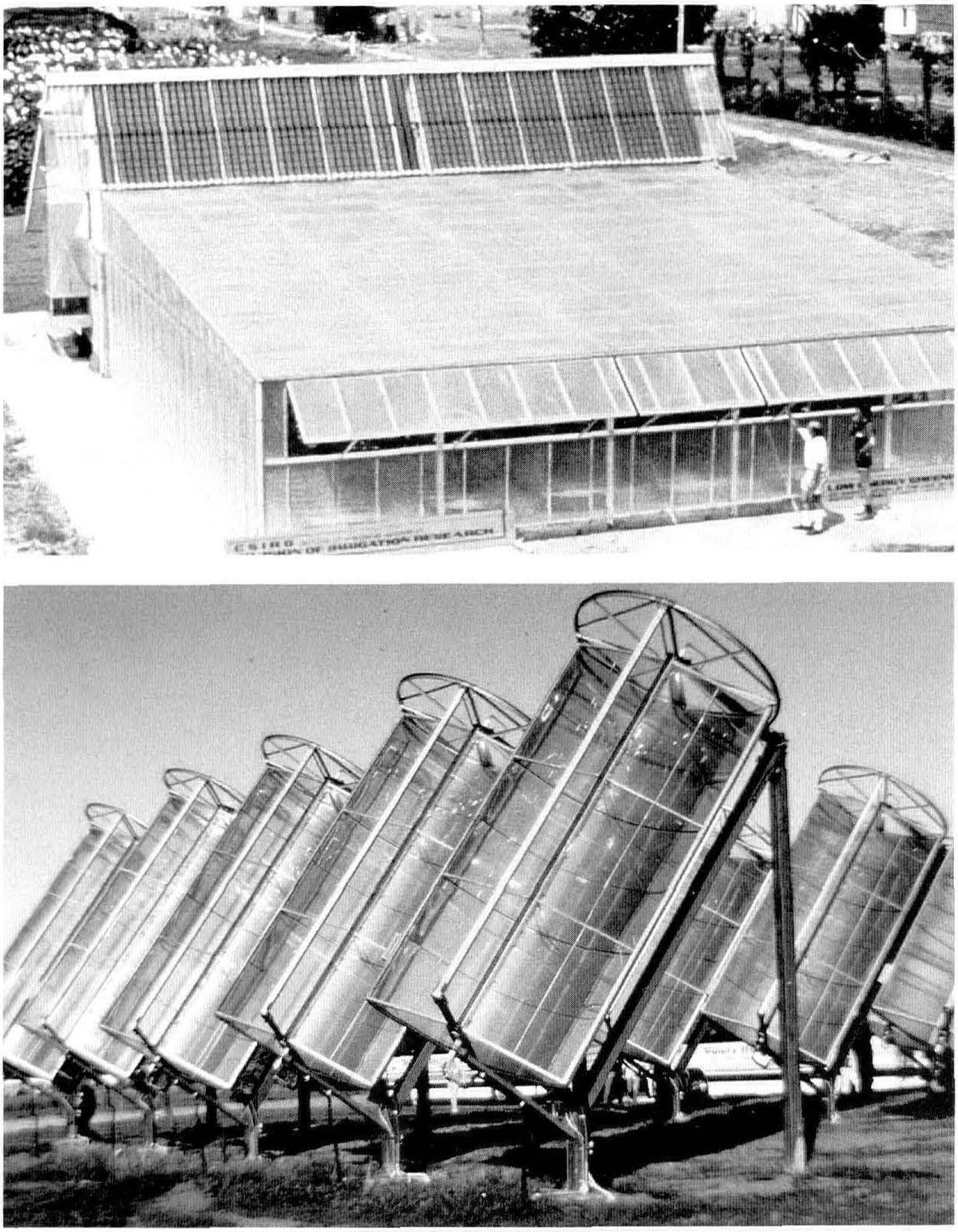

Figure 5. Examples of solar collectors currently being tried.

The ability for the greenhouse to collect sufficient energy to supply all heating requirements depends on the solar radiation levels outside the greenhouse. In southern areas of Australia, prolonged spells of cloudy weather can seriously reduce the efficiency of the system.

The C.S.I.R.O. has developed a solar air heating system that can be used to supplement the energy collected from within the greenhouse. This is a form of flat plate solar collector with a black painted metal absorber plate. This absorber plate is heated by absorption of the solar radiation. A layer of circulating air is passed through the collector, and this air absorbs heat from the absorber plate. The heat is stored in the greenhouse rockpile.

The second system of solar heating is the use of solar hot water heating. This concept of solar heating requires the installation of a large insulated hot water tank and the installation of a series of solar collectors with a sufficiently large surface area to heat the water to a suitable temperature (Figure 5, below).

The use of bench and underfloor heating systems utilizing water at temperatures between 40 and 50°C for circulation are tailor-made for solar hot-water heating, since even in the middle of winter it is possible to heat water to these required temperatures by solar means.

A number of large-scale experimental solar hot-water heating systems are in use, and to date their performance has been satisfactory. The major concern with all solar heating systems is the very high capital costs. This problem must be addressed by a search for lower-cost construction materials and techniques if solar heating is to become widespread in the nursery industry.

A NEW CONCEPT IN GREENHOUSE DESIGN

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Classical greenhouse design consisted of vertical sides and sloping roof much like frame homes and other utility buildings, only covered with glass. Glass provided good light transmission but had many air leaks. With the development of fiberglass, many glass greenhouses were converted following hail or wind damage, but greenhouse design changed very little. In the 1960s double polyethylene film plastics with air blown between the layers provided the emphasis for change. The natural curvature of a quonset structure allowed the polyfilms to be used with a minimum of corners or edges where tearing could easily occur.

Both the classical and the quonset designs had a maximum exposure of the glass or plastic covering to the elements. As a result of the very low insulating values, heat loss was tremendous. Conventional design generally had the advantage of roof and side vents to provide natural convection cooling. On the other hand, double polyfilm quonset-style greenhouses could be very tight in terms of air infiltration and air loss but were difficult to ventilate and cool. Low-cost electricity and improved exhaust fans absorption of the solar radiation. A layer of circulating air is passed through the collector, and this air absorbs heat from the absorber plate. The heat is stored in the greenhouse rockpile.

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When the cost of energy began to escalate in the 1970s, it became painfully obvious how inefficient greenhouses were. With a maximum surface exposure and an R factor* of about one, many greenhouse owners, especially in northern climates, went out of business.

Air-inflated poly over glass or fiberglass increased the R of the sides or roof of a greenhouse to about two, but even so, the heating requirements were staggering. Night-insulating curtains provided a major benefit but had the added complication of needing to be opened and closed daily. A general "tightening up" of the greenhouse and the addition of air-lock doors provided further savings. In most new construction and some older structures, north walls were converted to insulated conventional construction, much like the wall of a home, with little, if any, sacrifice in plant growth.

All of these energy-saving features were beneficial, but the savings did not keep up with climbing energy costs. Then came the emphasis on solar heating. In print and theoretically it sounds terrific. The sun *does* provide an awesome source of energy.

Solar collectors can collect vast quantities of heat when the sun shines, even when air temperatures are very low. The problem is how to store enough energy economically to last for the night or succeeding days when the sun does not shine. Many agricultural engineers, horticulturists, and others scrambled to refine and perfect a successful solar-heated greenhouse. Variations in solar collectors, heat storage, and insulating systems were numerous. However, the construction of these systems was expensive and awkward, and maintenance was high. For example, we designed a floor-heated, floor-heat-storage greenhouse, which used the space between the inner two layers of a triple layer air-inflated poly cover as the solar collector. Fuel consumption was reduced by nearly 70% compared to a conventional forced-air, natural gas-heated poly-covered quonset greenhouse of the same dimensions. However, during that winter there were two periods when conventional heating was required for periods of 6 and 11 consecutive overcast days, even though it was a very mild winter in north central Oklahoma. The following winter energy savings were only 43%.

FACTORS CONSIDERED AND DESIRED

The ideal greenhouse would have a minimum of opaque surface for heat buildup in the summer and heat loss in winter. It would have good ventilation and cooling. It would provide a

*Resistance of wall materials to heat transmission as compared to transmission through glass.

minimum uninsulated area for heat loss, yet enough light for the array of crops to be grown. If a cold weather insulation system is used it should be easy to operate and effective with a minimum of maintenance and expense.

Through experiments and experience, it was observed that up to a point the east and west walls of a greenhouse could be made of solid insulated materials like the north wall with little or no loss in crop performance and quality. This is due to the low sun angle during the winter months, which limits early-morning and late-evening light intensity.

Heat would be with fossil fuels, but the heat placement would be below the root zone of the crop. Forced-air heating stirs and maximizes the movement of warm air against the poorly-insulated light-admitting surfaces. On the other hand, a static bottom-heat system on which containers are placed heats most at the bottom of the container and least near the surface. Evaporative cooling occurs as water is lost from the surface of the growth medium. The temperature gradient from top to bottom of the container is therefore substantial. If the bottom heat is raised to the point where the surface of the growth medium is near 70°F, the roots in the bottom will be killed by excess heat. In spite of these complications, a static bottom-heat system holds the edge over forced-air heaters.

The ventilation system should work with the natural convective movements of warm and cool air instead of against them. Work with the roof vents in the quonset structures clearly demonstrated the advantage of roof vents. However, to be practical the greenhouse design must be such that vents can be provided in the high points.

THE FINAL DESIGN

A modified sawtooth design with the vertical surfaces facing south was chosen after all factors were thoroughly considered. By adjusting the height and slope of the sawtooth sections, good winter lighting could be obtained with a minimum of heat-loss surfaces. The sloping roof surface could be insulated in the fall and allowed to remain until spring. Thus no daily open-close curtains or apertures are involved. The peaks of a sawtooth design provide a natural ventilation point to discharge excess heat. If shade during the warm months is desired, it can remain in place the year round. During the summer the shade is effective in blocking out part of the sun, which at that time is overhead. On the other hand, in winter the sun has moved south so that all light enters the vertical face of the sawtooth. The sloping and shaded surface can, therefore, be insulated. The north, east, and west walls are insulated to R = 11 to a height of seven feet. The south wall is insulated up to the height of the containers sitting on the benches. Standard home-construction materials are used.

The interior of these solid walls is covered with reflective materials to diffuse light and minimize shadows. The heating system uses hot water in PVC pipe but without direct contact between the bottom of the container and the surface of the pipe. Using schedule 40 1-in. instead of ½ or ¾ in. PVC pipe on 5-in. centers will increase the system's capability to buffer temperature change. In addition, insulation is placed below the heat pipes in order to minimize downward heat loss.

THE STRUCTURE

The structure, oriented east-west, is 24 ft. by 60 ft. (two 12-ft. sections), with a frame and support posts of pressure-treated lumber. The 4-in. by 4-in. support posts are on 6-ft. centers along the north, center, and south walls with 12 ft. between rows. The 33 posts are set in concrete approximately 2 ft. deep. Headers of 2-by-4s, creating an L-shape, are constructed to connect the posts along the east-west axis.

The roof trusses are designed so that three 12-ft. 2×4's are used with no waste. The north wall is solid as are the east and west walls up to the base of the truss. These walls consist of 2-by-4s framing and ⅝-in. thick grooved fir siding on the outside and R-11 fiberglass insulation and corrugated galvanized steel on the inside. The corrugated steel is oriented vertically so that, as the sun moves across the horizon and strikes the many curved surfaces, light is reflected in all directions, especially off the inner north wall.

The south wall up to the bench height is also insulated. However, foil-faced urethane sheets were used, since the likelihood of moisture contact is greater.

The roof covering of choice was polygal polycarbonate in 4-by-12 ft. sheets. This provides a tough, durable surface with reasonable insulating qualities, good light transmission, and an acceptable cost.

Ten 12-in. non-powered, turbine roof vents were positioned at the peaks of the roof. There are four air inlets on the ends and along the south wall. Air transfer from outside into the greenhouse occurs as a result of natural convection.

The heating system consists of two 30-gal. propane-fired hot water tanks with a capacity of 37,000 BTUs each (output). The warm water is circulated by small in-line, centrifugal pumps approximately ⅛ horsepower through 1-in. schedule 40 PVC pipe on 5-in. centers.

Water temperature is controlled by the thermostat on the heater. Water flow and bench heating are controlled by a thermostat that controls the pump. This dual thermostat protects both the plants and the pipes from excess heat, while using a minimum of controls.

Wire-mesh panels 52-in. by 16-ft. (cattle panels) were placed below and on top of the 1-in. PVC lines to provide support for the PVC and a surface for flats or trays of containers. This ensures that no container is in contact with the PVC line; thus heat is transferred by air rather than by direct conduction. Foil-faced, ½-inch urethane insulation was placed beneath the benches to minimize downward heat loss due to convection.

PRIMING THE WATERING-HEATING SYSTEM

One of the greatest challenges with this system is removing all air from the hot water tank, pipe, header, and pump complex. If an upright water tank is used, install a vertical vent pipe at the high point of the system, including a threaded and fitting and screw-thread cap. Leave the cap off until start-up time. Be sure the tank is equipped with a pressure-relief valve.

Once the system is functioning properly, check all connections for leaks, including the cap on the vent pipe. Water can be removed from the system down to where it just reaches the bottom of the vent pipe. Replace the cap. This leaves the air in the vent pipe to be compressed as the water expands due to heating. However, this does not appear to be necessary since the PVC pipe expands more than the water upon heating. If the system is ever to be left unused in winter, automobile anti-freeze may be added to prevent damage.

PERFORMANCE

The winter of 1986–87 was mild for north central Oklahoma. The ½-in. thick foil-faced insulation sheets were installed in the roof on November 9. No reduction in light occurred because the sun was so far south. There were no shadows visible in the greenhouse as a result of diffusion and reflection provided by the design.

The coldest temperature outside was 9°F (−13°C) while the lowest temperature inside was 47°F (+7°C) even though only one hot water tank was used with lines in one of the four benches. A 12-in. snow in January filled the valleys of the roof, but no load problem could be detected.

CHANGES CONSIDERED

If the structure was rebuilt today, the vertical height of the saw-tooth would be 6 ft. instead of 4 ft. and truss length would be 16 ft. This would allow the insulation to be installed a few weeks earlier and stay later. In addition, some sunlight would be reflected off the underside of the insulation and straight down onto the benches. Additional air inlet vents would be built into both ends along the south side to assist natural convection ventilation. All other factors would remain the same. It is important to note that this is an experimental structure and has been in use for only one year as of this writing. Additional adjustments in the design and function may become apparent with time.

Details of construction and priming the water-heating system are available from the author.

DEVELOPMENT OF A NATURAL VENT GREENHOUSE

DOUGLAS A. HOLMBERG

Pleasant View Wholesale Nursery, Inc.
1321 N. Valrico Road
Valrico, Florida 33594

The development of a natural vent greenhouse is one in a series of developments aimed at more efficient plant propagation in my particular set of circumstances. Development of the concept of this house began in 1977.

Up until then, my nursery's efforts were almost exclusively to produce citrus in several sizes for dooryard sales through retail outlets. Planned expansion of woody ornamental production on 25 acres mandated the development of efficient buildings and production tools for the specific purpose of propagation. At this time (1977) most woody ornamental propagation in Florida was done in open sun under mist using a peat bed or rose pots with a peat:perlite medium.

As recently as 1970, there was opposition to including a propagation unit inside greenhouses at Florida vocational schools as county commissioners felt putting a propagation unit inside a greenhouse was a huge waste. However, seeing production problems throughout the state convinced me that efficient climate control was essential with woody ornaments even in Florida's subtropical climate.

The style of the buildings that I saw the pepper growers build in Webster, Florida, appeared to be efficient. A very innovative structure seen at Wetherwood Nursery in Dover, Florida proved the desirability and versatility of the new innovation of double poly covering. The development of double poly covering has made it possible to construct a very inexpensive, but effective propagation structure. Ventilation comes in through openings the length of the house on the side and out through gable ends.

Nine wood-frame structures were eventually constructed in 1978–79 using this basic plant at a cost of approximately $1,500 per building. The amount seemed reasonable in light of the fact that we writing. Additional adjustments in the design and function may become apparent with time.

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Nine wood-frame structures were eventually constructed in 1978–79 using this basic plant at a cost of approximately $1,500 per building. The amount seemed reasonable in light of the fact that we could turn out a crop of 60,000 quality finished liners every three to four months. After several crops we found that one of the shortcomings of the wood frame was the continuing sanitation problem. These houses withstood two hurricanes, but effective as the houses were, opening and closing the sides and ends was a heavy labor cost. We eventually changed construction, as explained later.

Benches and trays were the next considerations. Several alternatives were evaluated, but the necessity of having cool conditions for liners in the summer and warm conditions in winter, made placing the benches on the floor seem desirable.

Selection of a tray that could be filled and handled efficiently while producing a quality liner that could be held for extended periods of time proved to be a challenge. Tests on every available tray on the market yielded information but there was not one that seemed suitable for use under our conditions. We use a spinner sprinkler system instead of mist heads as we cannot afford the time and labor cost of unclogging fog nozzles. We experienced drainage problems with every tray we tested.

The end result was development of our own tray. It is designed for efficient filling and handling and has a shape conducive to desirable root development. There is a large bottom hole for air pruning and drainage. The root development was so dramatic that a single eight-week gardenia liner planted out in the old style egg can had formed such an extensive root system that the entire plant, pot and all, could be picked up by the plant after only six weeks in the container.

Since 1978, production of woody ornamental liners has varied from one to three million per year. In 1984, we developed a new line of six trays that were needed for our increased nursery production. The new style tray is designed so that liners can be held for an extended time without root damage.

Review of the total propagation program showed that we had an effective, efficient program but that new developments in houses and benches were necessary to improve quality further, lessen labor demands, and reduce sanitation problems. Employees damaged the floor benches by walking on them, and sanitation problems with wooden benches and rusty wire caused losses of valuable crops.

The development of a portable bench eliminated wood benches and rusty wire and gave us flexibility in the propagation process. Trays are always out of contact with the ground, efficient drainage is assured, and air-pruning promotes branched feeder root systems. The unit can be moved out of the propagation house anytime after rooting and placed on plastic, ground cover, or other surface with the same continuing, dry sanitary support. This reduces costs dramatically and allows utilization of space more efficiently. Houses can be emptied, sanitized, and refilled as needed.

A new metal frame house of 16,000 $ft.^2$ with cooling pads, exhaust fans, double-poly covering, and rolling benches was constructed. It proved to be effective, but disappointing. It had less sanitation problems, but the maintenance of the cooling pads and exhaust shutter fans was expensive. If anything went wrong, the whole crop was endangered unless the problem was discovered and corrected at once.

A greenhouse using natural ventilation was constructed in 1987. It was designed to take advantage of the movement of rising warm air out of a ridge vent while drawing cooler air in through side openings.

The essential elements of the ventilation in the natural vent greenhouse are:

1. An aperture at the ridge, the full length of the roof and
2. An aperture the full length of the side or sides of the house.

These apertures are opened and closed, utilizing a polytube inflated with a 1/20 h.p. fan. For the prototype, simple PVC ball valves are used to control movement of air to each tube. The apertures may be fully or partially closed or opened depending on temperature requirements. Regulating the size of the opening regulates air flow and effectively controls temperature.

We anticipate adding programmable controls in the future to eliminate labor costs, minimize spread of temperature, and maximize heat retention in winter.

Although our facilities are designed so that we could use fog, we are content with our propagation program at this point and will probably not add a fog system. The combination of our new trays, the portable bench, and the naturally vented greenhouse, we feel, gives us a near ideal facility for woody ornamental propagation at our location. In addition, our system could easily be adapted to grow numerous other crops.

HIGH HUMIDITY PROPAGATION USING SWEAT BOX METHOD

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In these days and times of intermittent mist, high humidity greenhouses, and tissue culture, you may wonder why anyone would consider cold-frame propagation. When the ornamental nursery industry was getting started in this country 100 or more years ago, cold frames undoubtedly were the means used for most propagation of hardwood cuttings. The two best reasons for taking a second look at this method are economy and simplicity.

The increasing interest being shown by growers in the direct rooting of cuttings in pots makes the sweat box worth thinking about. One of the main drawbacks to direct rooting is the increased propagation area required to handle all these pots. If this area has to be placed under a mist system or in greenhouses, costs begin to increase proportionately.

With the sweat box there are no greenhouses, mist heads, or any other mechanical parts required. Basically, the system involves enclosing a ground bed or liner bed in an airtight environment, thereby creating a high humidity atmosphere around the cuttings. We do this by the use of 4-mil white poly film supported by concrete reinforcing wire, similar to the method commonly used for winter protection of liners. The heat generated under this cover, in conjunction with moisture derived from the rooting medium, produces almost 100% relative humidity. In the absence of air circulation or drafts, part of this high humidity condenses and forms a thin film of moisture enclosing the leaf surface of the cuttings. This film prevents moisture loss from the leaves due to transpiration. Mist propagation depends upon replacing moisture lost from evaporation; with this system we prevent evaporation from occurring.

The rooting beds should be located in a partially shaded area, either in a shade frame or under trees. Partial shade is needed to prevent excessive heat buildup since the ideal time for this propagation method is June through August.

Peat or plastic 3 or 4-in. pots are placed on the bed and filled with rooting medium. Almost any material or combination of materials commonly used in propagation can be used in the sweat box as long as it has high moisture retention but is still fairly well-drained. At Wildwood Nurseries we use 3-in. square peat pots filled with a commercially-prepared rooting medium called Metro Mix 300 for azaleas and camellias. For most other species we use fine pine bark and field sand in a three-to-one proportion. After the pots

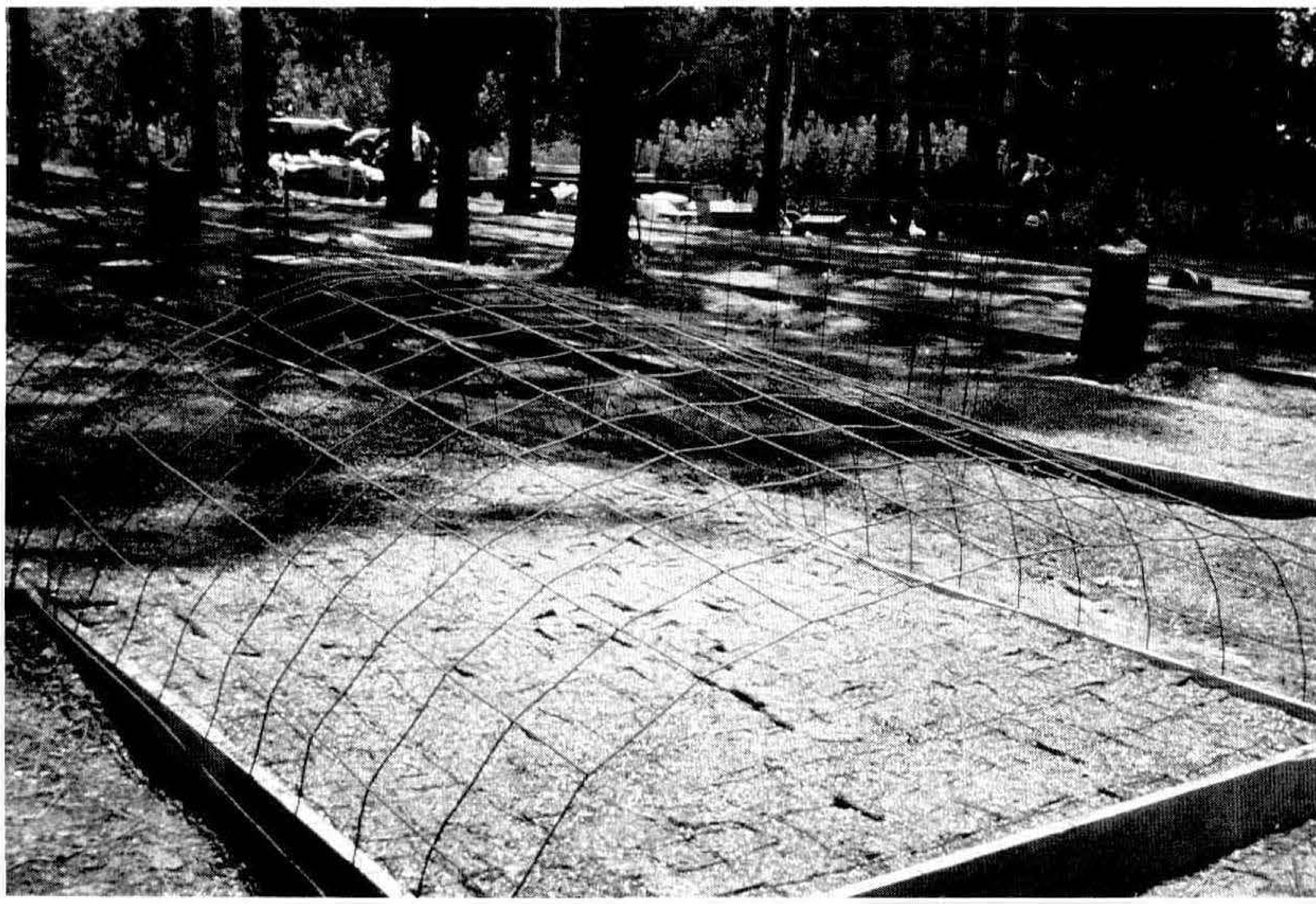

Figure 1. Bed with concrete reinforcing wire in place, ready to cover with plastic.

are filled, the concrete reinforcing wire is put in place, as shown in Figure 1, then covered with polyfilm, sealed and fumigated with methyl bromide gas.

Allow at least 48 hours of fumigation before uncovering and an additional 48 hours for excess gas to dissipate. It is important that the bed be thoroughly dampened before sticking your cuttings because you are depending on this moisture to provide the necessary humidity during the rooting period. The bed will probably remain covered from 10 to 12 weeks, depending on how fast the various species form roots.

Cuttings are usually put in during June, July, and August. There is no change in the manner in which cuttings are made. It is advisable to use a fungicidal bath to insure complete coverage before sticking cuttings. After cuttings are stuck, the bed is sprayed with a fungicide, covered with polyfilm, and completely sealed. When put in during this time the cuttings will have time to root and be hardened-off before cold weather.

The hardening-off procedure requires fairly close attention. Observe your cuttings regularly after the fourth week. By 4 to 6 weeks new growth will be visible and roots will be forming. At 10 to 12 weeks the airtight atmosphere is gradually broken by cutting a few holes in the polyfilm covering. Since this same plastic cover will be used for winter protection, be careful to make cuts that can be resealed at a later date. By October or early November all beds can be gradually uncovered and allowed to harden. Water thoroughly and spray with fungicides and insecticides as you would any other rooted cuttings.

Before the first frost, recover the beds for winter protection. If they are well watered at this time, they will usually carry until they are permanently uncovered the following spring. The time required from cutting to finished liner is about 10 months.

PROPAGATION OF CALLUNAS AND ERICAS IN THE UNITED KINGDOM

MICHAEL L. DUNNETT

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Belbroughton Road, Blakedown,
Kidderminster, Worcs. DY10 3JG, England

INTRODUCTION

Before talking about propagation perhaps we should say something about the plants.

Calluna vulgaris. (Ling) is indigenous to the northern, western, and southern moorlands of the British Isles, as well as other parts of Europe and Asia Minor. As a garden plant it is easily grown in an open situation but most must be planted in acid soil. There are some, however, that will stand a certain amount of alkalinity. The plants are both attractive as flowering plants from July to November and as foliage plants for early spring and autumn colour. There are literally hundreds of cultivars now available from British nurseries.

Erica. (Heath)—Several species and again several hundred cultivars are propagated and grown in the United Kingdom. In fact, it is possible to have ericas in flower most months of the year. The species of particular significance are:

E. herbacea (Syn. *E. carnea*)	Winter-flowering heath	flowering November–April
E. ciliaris	Dorset heath	flowering July–October
E. cinerea	Bell heather	flowering June–September
E. × *darleyensis*	*E. herbacea* × *E. erigena*	flowering February–April
E. tetralix	Cross-leaved heath	flowering June–October
E. vagans	Cornish heath	flowering July–October

All, except *Erica herbacea,* require acid soil conditions. This will tolerate a slightly alkaline soil.

Most cullunas and ericas are dwarf-growing mat-forming plants. This makes them ideal for small gardens. It is a common practice to plant with dwarf conifers, which add height to the planting and enhance the year-round color of the planting scheme.

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THE MARKET

It is estimated that retail sales in the British Isles are in the region of 12 million pounds sterling per annum. The production at Blakedown Nurseries is in excess of 500,000 units per year, with a wholesale value of 250,000 pounds.

We produce three sizes: ½ litre, 1 litre, and 3 liter, based upon metric volume of the container. The ½ litre size has been grown by ourselves and other nurseries for many years. Larger pot volumes have been introduced in the last few years.

Most callunas and ericas are sold through garden centers to the private gardener. However, there is a steady and increasing demand for the more robust cultivars by landscape contractors for amenity planting.

PROPAGATION

Mother stock. We grow mother plants both in outside beds and in 1-litre pots. As pot-grown plants are often protected, it gives us the opportunity to "forward" cuttings for early propagation.

Propagation technique. Softwood cuttings are taken between late May and the end of September. They are collected from mother stock, which has been pre-disinfected by a fungicide. Nodal and heel cuttings are used. Cuttings are prepared close to the propagation area. Knives are the "throw-away" blade types, saving sharpening time. The polythene workbench tops are washed daily with hypochlorite.

Insertion of cuttings. Cuttings are inserted into modular trays, each containing 247 cells. The rooting compost, which is prepared by hand, consists of ⅔ sphagnum peat and ⅓ polystryene granules. The filled trays are stood directly onto sand beds heated by hot water in 22mm alkathene pipes. The heat source is provided by dual-energy 28-second oil and off-peak electricity. A bed temperature of 15°C is maintained.

The misting unit is controlled by a "wet leaf". Beds are covered with a fine mesh net, which allows 40% of the mist to percolate. This technique has proved very beneficial as it gives extra shade, a cool micro-climate and, as the propagation house is ventilated by fans, no disruption to the mist. Rooting takes between 3 and 5 weeks, dependent on the time of the year and the cultivar.

Aftercare. Rooted cuttings are gradually "weaned" from the mist unit, eventually being moved to storage houses. Regular sprays of foliar feed are given to ensure starvation does not occur prior to potting on.

Potting on. Our cropping program depends upon the time that we wish to market our plants. The ½ litre program is scheduled to produce two crops. Crop one is marketed May to August. Plants intended for this crop are potted into 5.5-metre × 18-metre polythene tunnels in September. The tunnels are clad with clear 400g film. The lightweight film ensures good light during the short autumn and winter days. Crop two is marketed between September and March. The rooted cuttings are potted-on outside during April. We use a 70% sphagnum peat and 30% bark potting compost. To each cubic metre we add:

2.5 kg	12-to-14-month Osmocote plus
0.75 kg	12-to-14-month Sierrablen
1.2 kg	magnesium limestone
400 g	Rovral.

We intend to produce a compost with pH 5.5.

The rooted cuttings are potted from a mobile potting unit that is capable of producing 24,000 7cm pots a day. A gang of five people operate the unit. They work a two-shift system, which equates to a 16-hour day. Plants are stood down pot thick on sand beds. Watering is by overhead Mamset nozzles. One-litre and three-litre plants are potted on using ½-litre stock as liners.

PROPAGATION OF A SELECTION OF NEW ZEALAND NATIVE SPECIES OF COMMERCIAL SIGNIFICANCE

MALCOLM P. WOOLMORE

Box 81022

Whenuapai, New Zealand

At Lyndale Nurseries situated in Whenuapai, Auckland, the problem of what not to grow is often more difficult to decide than the more commonly asked question of what to grow. There is a need to be continually assessing cultivars and market response to them.

When we identify a plant with "potential", resources have to be allocated to produce a required number. Given a production limit something has to be sacrificed—what not to grow. The two species discussed in this paper add to the dilemma of what not to grow.

In identifying what criteria are necessary for shrubs of commercial promise or significance the demands of the market are paramount. The market specified for these plants is for flowering shrubs with end use as patio plants in pots, or in rockeries and small courtyard gardens.

These requirements are:

1. A long flowering period.
2. Good shape and form, irrespective of flowers.
3. Good colour of flower contrasting with foliage.
4. A height of under two meters and shape suitable for a life of container growing.

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Hence we have a good place to start identifying and developing species that would fit the criteria.

The genus *Sophora*, while not confined to New Zealand, is often identified with this country. Indeed, the flower of one member of the genus is often symbolized as representing our culture.

Recent work carried out at the Horticultural Research Center, Research Division, Ministry of Agriculture and Fisheries, Levin, has resulted in the release of a number of cultivars of *Sophora tetraptera*. One of these, *Sophora tetraptera* 'Early Gold' forms a compact, small pyramidal tree with dark green foliage during summer but it is semideciduous at flowering. Flowers are a lemon-yellow with a light green calyx.

The propagation of *Sophora* by cuttings is not easy. Best results seem to be achieved by taking cuttings of new growth 10 to 15 cm long in either of two periods, early spring (September) or towards the end of summer (February–March). We make a single wound opposite the basal bud, treat with a fungicidal dip and either 0.8% IBA or IBA + 0.4% NAA, then insert the cutting into a mix of 90 percent pumice and 10 percent peat and place it on bottom heat of 25°C with mist.

This procedure has given 80% rooting in six weeks. The cuttings, once rooted, progress rapidly. However, care must be taken when potting the rooted cuttings, as the newly initiated roots are easily knocked off. The slightly pendulous habit of this cultivar and its early flowering (July and August) qualities will ensure demand for a well-grown specimen.

The second species identified in this paper is *Metrosidros carminea*. This interesting specimen is listed as an endangered species as it has been recorded as existing in only six wild localities today. The genus *Metrosidros* is made up of about 30 species of hardy evergreen trees, shrubs, and climbers and is found in New Zealand and tropical Polynesia. The species endemic to New Zealand are amongst the few highly coloured native trees found here.

Metrosidros carminea is a particularly unusual specimen in that it is generally listed as being a climber. However, this pertains to its juvenile form. As a climber it can grow across a rocky face or up a canopy tree reaching heights of 10 meters or more. Once it reaches the top of a rocky face its new growth is in adult form, which results in a bushy shrub of approximately 1 meter in height. Grown from a cutting of adult wood, this plant will come into flower quickly and produce a bushy shrub suitable for growing in tubs.

We do not find the propagation of *Metrosidros* species by cuttings easy. We achieve 40 to 50% success on average, an indication of the difficulties of these species.

Metrosidros carminea is best attempted from cuttings of new wood made in late summer (February or March). Use semisoft or ¾ softwood material which is greenwood with brown at the base. Dip in a 0.1% IBA or Seradix I as a quick-dip. The dipped cuttings are then planted into a 90:10% mix of pumice, sand and peat, then placed on bottom heat of 25°C with mist. Results are relatively quick with this type of soft material, the first roots showing in 3 to 4 weeks. A 30- to 40% rooting rate has been our initial experience with this species. This low percentage has led us to offer material to a local tissue culture laboratory that has had success with reproducing other *Metrosidros* species. We have been fortunate in getting *Metrosidros carminea* established in culture.

Specimens taken out of micropropagation situations are in their juvenile or climber form, not the desired adult form. However, they advanced to the adult form within a period of approximately three months from deflasking.

Due to the still experimental nature of this material from culture, I cannot comment on the time lapse to flowering at this stage. However, we feel this specimen has much to offer as a potted tub plant or a small garden shrub with its unique masses of carmine red flowers.

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1. Metcalf, Lawrence James. 1975. The Cultivation of New Zealand Trees and Shrubs. A. H. Reed, Wellington, N.Z. pp. 292.
2. Godley, E. J. 1975. Kowhais and their flowering. *New Zealand's Nature Heritage*, 5:1804–06.

VEGETATIVE PROPAGATION OF FOLIAGE PLANTS

R. T. POOLE AND C. A. CONOVER

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Apopka, Florida 32703

The various methods of propagating foliage plants include making cuttings, airlayers, divisions, tissue cultures, sowing seed, and spores. Vegetative propagation by cuttings is the most popular. Cuttings are sometimes placed in flats or benches, but placement in pots is the method used most. Although direct sticking requires more space, growth is usually accelerated and labor for transplanting is reduced. Less labor is a big advantage as labor costs continue to increase.

The vigor of the stocks plant is important. They should be healthy, turgid, free of insects, diseases, and nutritional deficiencies (Table 1). Single-eye cuttings of *Ficus elastica* 'Decora' stock plants grown in full sun and fertilized with 21 grams of 18-6-12 per softwood material which is greenwood with brown at the base. Dip in a 0.1% IBA or Seradix I as a quick-dip. The dipped cuttings are then planted into a 90:10% mix of pumice, sand and peat, then placed on bottom heat of 25°C with mist. Results are relatively quick with this type of soft material, the first roots showing in 3 to 4 weeks. A 30- to 40% rooting rate has been our initial experience with this species. This low percentage has led us to offer material to a local tissue culture laboratory that has had success with reproducing other *Metrosidros* species. We have been fortunate in getting *Metrosidros carminea* established in culture.

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The various methods of propagating foliage plants include making cuttings, airlayers, divisions, tissue cultures, sowing seed, and spores. Vegetative propagation by cuttings is the most popular. Cuttings are sometimes placed in flats or benches, but placement in pots is the method used most. Although direct sticking requires more space, growth is usually accelerated and labor for transplanting is reduced. Less labor is a big advantage as labor costs continue to increase.

The vigor of the stocks plant is important. They should be healthy, turgid, free of insects, diseases, and nutritional deficiencies (Table 1). Single-eye cuttings of *Ficus elastica* 'Decora' stock plants grown in full sun and fertilized with 21 grams of 18-6-12 per

12-in. pot had 97% survival rate while 70% was obtained from stock plants fertilized with 7 grams and grown in 30% shade. Maximum leaf surface should be left on cuttings since reduction in leaf surface reduces production of carbohydrates and natural hormones needed for growth and root development.

Many propagators do not appreciate the importance of stock plants. For example, they may wonder why they are losing variegation in a cultivar as they continue to propagate from plants that are part of their sales inventory. The problem is that the best plants are being sold.

Table 1. Cutting weight of *P. oxycardium* and subsequent vine length.

Cutting (g)	Vine (cm)
4.4	20
2.9	15
2.4	14
1.8	10

The most frequently used cuttings are terminal stem (tip) and single node (single eye). Leaf cuttings and cane are also used. Tip cuttings are used frequently for *Dracaena, Aglaonema, Peperomia,* and *Dieffenbachia. Dracaena* and *Aglaonema* cane propagation is widespread. Much of the material is coming in from the tropics and seems not to suffer from storage. About 1 in. should be removed from the bottom before sticking the cane. *Ficus* may also be air-layered, but it is not necessary to propagate it in this way.

Since plants are frequently sold soon after rooting, tip cuttings are usually 4 to 6 inches long. The smaller cuttings usually root faster and require less space. Only foliage that is damaged or will have its base in the medium should be removed. A poorly-rooted cutting will make it if properly cared for.

Leaf-bud cuttings are used to propagate foliage plants that grow as vines. A single-eye cutting consists of a stem section, usually 1 to 1½ inches long, with a node and attached leaf. Soft tips and hard bases of vines should be avoided. Cuttings are placed with the bud at or slightly below the rooting medium. Initial cost is small, but a salable plant requires 6 weeks to 3 months. Single-bud cuttings of some of the large *Ficus* species produce 12-in. stems in six months.

A few foliage plants, such as Rex begonia, are propagated by leaf cuttings. A large number of plants can be obtained from a small amount of material.

Dracaena fragrans 'Massangeana', *Yucca elephantipes* and some large *Dieffenbachia* are rooted by long cane cuttings. Canes of *D.* 'Massangeana' used for propagation can be as long as six feet. Fresh cane should be obtained and the lower ½ inch removed before placement in sawdust or peat. Canes should be treated as carefully as delicate leaf cuttings. They should not be exposed to heat or drying conditions. *Dieffenbachia* cane is usually cut as one or two nodes per section. Once healthy cuttings are selected, the proper environmental conditions should be maintained.

The propagation medium should be easily obtained, uniform, and available in consistent quantity. The medium should support the cuttings and allow easy removal after development of root systems. Satisfactory rooting of cuttings will occur with a pH of 5.5 to 6.5, although good rooting can occur at a wider range. Good water-holding capacity and aeration of the medium are important characteristics. The medium should hold enough water for adequate absorption by the plant, but there must be ample pore space for oxygen to penetrate the rooting medium. Many media have been developed that meet these requirements. Superphosphate should not be incorporated into the growing medium because some plants such as *Dracaena, Yucca,* and *Chlorophytum* are damaged by the fluoride found in superphosphate (Table 2).

Table 2. Influence of SSP* and basal-end removal on shoots/yucca cane.

	SSP (kg/m^3)	
Base removed	0	4
Yes	3.9	2.0
No	2.6	2.8

*Single superphosphate

Light, water, and temperature are critical for proper rooting of foliage cuttings. Maximum light should be utilized. The best light for growth of the rooted plant is best for the cutting if temperature and humidity are optimum. Cuttings with insufficient light will frequently initiate roots but will not produce enough carbohydrates to promote shoot growth. Light levels of 2,500 foot candles can be used with most foliage plants when humidity and temperatures are optimal. Although the light level should not be too high, most foliage plants will take more than we originally believed.

Some foliage plants need little moisture while initiating roots; others need high humidity to prevent wilt and encourage rooting. Mist systems provide the best method for maintaining moisture. Duration of mist and frequency of misting can vary considerably depending upon light intensity, time of year, and season. Thirty seconds every 30 minutes is satisfactory for most situations.

Slow rooting is often caused by low medium temperature. Root initiation is improved by media temperatures as high as 90°F, but root growth is inhibited at this temperature. Maximum temperature for root growth of most foliage plants is 80°F. If medium temperatures are below 70°F, root initiation and growth are greatly inhibited.

Fluorine in the water can damage cuttings. It is also often present in superphosphate. Damage often shows as leaf spotting and burning. Increasing pH may help.

Most foliage plants root readily when they are obtained from healthy stock plants and placed in an optimum rooting environment, but there is slight benefit with the use of rooting hormones for some plants (Tables 3 and 4).

Table 3. Cutting response of selected foliage plants to Hormodin 2.

Postive	None
Aphelandra 'Dania'	*Aglaonema* 'Silver Queen'
Ficus benjamina	*Dracaena sanderana*
Peperomia obtusifolia	*Maranta leuconeura*
Polyscias balfouriana	
Syngonium podophyllum	

Table 4. Effect of Hormodin and soil temperature on number of roots of *Aglaonema* 'Fransher'.

	Soil Temperature (°F)	
	66(10 wks)	86 (5 wks)
Control	5.5	7.7
Hormodin 1	5.6	9.3
Hormodin 2	7.2	17.2
Hormodin 3	7.4	18.8

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PROPAGATION OF DWARF NANDINA CULTIVARS

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Dwarf nandinas (*Nandina domestica*) are relatively easy to root. However, there are three problems: It is hard to obtain enough cutting wood; the work is very labor intensive; and, third, the proper application and frequency of the mist is critical.

At the Hines (Houston) facility, we grow four cultivars of dwarf nandinas: 'Compacta Nana' ('Purpurea Nana'), Harbour Dwarf, 'Gulf Stream' (Plant Patent 5656), and 'Moon Bay' (Plant Patent 5659). We use the same propagation techniques for all four.

All of the propagation wood is collected from container-grown material which is a very time consuming job. We use the tips only with no brown wood. Usually the stem part of the cutting will be ½ to 1½ in. long. The wood is stored in a walk-in cooler at about 50°F for up to 48 hours, but preferably no longer than 24 hours.

The cuttings are prepared indoors. All we do is strip off a few bottom leaves, just enough so that the foliage is not too thick during the rooting process. On 'Harbour Dwarf' we also reduce the overall diameter of the foliage. We occasionally recut the basal end if the cutting is too long. The cuttings are bundled into groups held together by a rubber band and then quick-dipped into a solution of Benlate and Agristrip at the recommended rates.

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The cuttings, still in bundles, are next quick-dipped into a solution of 1250 ppm IBA and 500 ppm NAA. The cuttings are all direct stuck into a new 2¼-in. pots, one per pot. We hold the cuttings by the leaf petioles and stick them to the tip of the stem, many times completely burying them. This process is another operation that is more labor-intensive than usual. The medium we are using is pine bark, peat, and sand, 2:1:1(v/v/v); 2½ lbs. of 18-6-12 (8 to 9 months) Osmocote is added to the mix along with lime and Micromax.

The pots are then placed in a 47% shade mist area where we closely monitor the mist. We prefer to root them in an area that has the parasol nozzle (¼ E 5.8) by Spraying Systems. This nozzle gives a fine spray with low water volume. However, we will use spinner type nozzles occasionally. It is very important not to overmist this plant because the foliage retains a lot of moisture. Overmisting generally results in an increased level of fungal problems. We do mist normally for the first 2 to 3 days after sticking, then cut the mist back. In Houston that usually means we start the cuttings on 15-minute intervals and then increase to 30 minutes. If it does not rain on the crop, we normally have to water the soil about every 10 to 14 days because the medium does not stay moist enough from the mist water. We also carefully check when the mist turns off for the day, which is usually two hours before sunset.

The cuttings usually root in 3 to 4 weeks and are off of the mist in 5 to 6 weeks. In another 5 to 6 weeks, the plants are ready to be shifted into gallon containers. We have noticed that root initiation first starts at the basal end of the cutting, but in about 3 weeks roots appear up the entire stem. The change in leaf color is very noticeable during the rooting process, changing from green to a burgundy color.

We have been successful rooting dwarf nandinas almost any time of the year. We have not tried to root them during the spring flush, however. Normally, 80 to 90% of the cuttings root.

During the winter we frequently take cuttings from liners grown in a quonset house without heat. For these cuttings the only change is that they are rooted on bottom heat at 72° to 75°F. For any cuttings that come from outdoor-grown material then, we also change the hormone concentration to 1870 ppm IBA and 1000 ppm NAA. They also are put on bottom heat.

In conclusion, dwarf nandinas are easy for us to root with the above procedures.

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LIGHT AND TEMPERATURE SENSITIVE MIST CONTROLLERS

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Abstract. This paper details available methods of controlling mist propagation systems with environmental sensing. Control objectives, similarities, differences, and interrelationships with fog systems, sprinkler cooling, and watering controllers are discussed.

MIST SYSTEMS

Misting is the primary traditional method of controlling transpiration loss and foliar overheating for propagation. Misting is now being replaced in many propagation applications by fog.

Fog or atomized mist systems provide better control of air moisture content for desired results in controlled environments; however, fog systems have limitations in shade house and outdoor areas where wind tends to carry off the extremely fine fog particles before the fog can effectively alter the propagation microclimate. Fog is also much more expensive than mist systems so mist will be in use for years to come.

Mist systems with larger particle sizes can be used to get water droplets to the leaf surfaces within a propagation area; subsequently the water droplets evaporate increasing the air moisture content in the leaf microclimate and cooling the leaf surface. The objective of mist systems is to maintain turgidity and reduce stress during propagation.

PRIMARY CONTROL OBJECTIVES

Control objectives for propagation mist, propagation fogging, fog cooling, sprinkler cooling and watering are listed because of the interrelationships between them in actual operations. Systems are interdependent because all consume water and require constant operating pressures to provide uniformity. Mist, sprinkler cooling, and watering can involve the same physical water application system used with a change in control (and sometimes a nozzle change) for different stages of growth. Fog systems can be used simultaneously for both propagation and cooling as needed with the proper controls.

Propagation mist. Very short durations of time (usually 3 to 15 seconds) should be used for misting. The time length for each zone should be selected to provide the shortest "on" time required to achieve acceptable uniformity of foliar wetting.

Time between mist starts should vary as needed to provide the desired balance among:

1. Air moisture content in the foliar microclimate
2. Temperature of the leaf surface
3. Soil wetting
4. Water consumption
5. Standing water in misting area.

Propagation fogging or humidification with humidity generating fans. Duration of fog system application should be balanced among the following (given in priority order):

1. Long enough duration to provide uniform results
2. Short enough to prevent foliar, soil, or floor wetting
3. Short enough to prevent wetting due to sensor lag (time required for sensors to record actual conditions)
4. Long enough to provide the desired maximum air moisture content
5. Subsequent stages of fog started and run in accordance with these guidelines if the initial stage(s) running continuously cannot maintain a high enough air moisture level

Time between fog system starts should vary as needed to:

1. Start as much time in advance of requirement as needed to allow for system charging if required
2. Maintain the desired minimum air-moisture content

Fog cooling. Duration of fog system application should be balanced between the following in priority order:

1. Timed short enough to prevent unwanted foliar, soil, or floor wetting
2. Timed to account for sensor lag
3. Limited by a maximum air moisture content
4. Timed long enough to reduce the temperature to the lowest cooled temperature desired
5. Subsequent stages of fog started and run in accordance with these guidelines if the initial stage(s) running continuously cannot maintain a low enough temperature

Time between fog-system starts should vary as needed to:

1. Start as much time in advance of requirement as needed to allow for system charging if required
2. Maintain the desired maximum temperature

Sprinkler cooling. Short duration times (usually 3 to 45 seconds) should be:

1. Long enough to charge the lines and provide full pressure to sprinklers

2. Least amount of time required to achieve acceptable uniformity of foliar wetting

Time between starts should vary as needed to provide the desired balance among:

1. Temperature of leaf surfaces
2. Air-moisture content in the foliar microclimate
3. Minimal water consumption
4. Minimal soil wetting

Watering. Long application times (typically 15 minutes to 12 hours) should be:

1. Short enough to prevent unnecessary run-off of water (may require multiple application per day)
2. Long enough to charge the system fully and provide acceptable uniformity of water application
3. Least amount of time required to achieve media or root wetting desired

Time between starts should vary as needed to:

1. Allow for system charging if required
2. Maintain the desired minimum medium or root-moisture content

MEASUREMENT METHODS

Direct Sensors

Air-Moisture sensors:

1. Humidistats with hair elements (slow)
2. Wet bulb/dry bulb sensors (high maintenance)
3. Electrical sensors that vary resistance with humidity changes (expensive, high maintenance)

Wetted surface and media-moisture content sensors:

1. Screen-weight switch (high maintenance)
2. Pot-weight scale switch (high maintenance, not sensitive enough for mist)
3. Media-moisture content sensors (require soil wetting, and time to react)
4. Electrical sensors that vary resistance with surface water changes (high maintenance)

Plant sensors (for future—not economically viable now)

1. Plant-tissue-moisture content sensors
2. Plant tissue temperature

Indirect sensors

Predictors:

1. Light: most effective predictor of stress change, reacts to sun level and weather
2. Air temperature: helpful in indicating high stress times in conjunction with light sensing
3. Wind speed and direction: expensive, helpful for outdoors
4. Time: poor predictor, even multiple timing changes per day cannot keep pace with stress changes

Present Optimum

Controller sensing and control method. Existing sensor capabilities and costs are such that the direct sensors are best only for selected installations. Relative humidity sensing is needed for fog systems, and large water systems need to be controlled by electronic soil-moisture sensors.

Misting applications utilize water droplets too large to enable a relative humidity sensor to react quickly enough to prevent over-wetting. Soil-moisture sensors require soil wetting which is not desired with misting systems. Surface-water sensors require extremely high maintenance, which makes them unsuitable for most horticultural applications where time is also short.

Each of the direct sensing methods also requires one or more sensors per zone, which is not feasible for multiple zone applications.

Indirect sensors that can be used to predict when to mist offer several advantages for misting system control. Light, temperature, ambient relative humidity and wind are "universal stress agents" that are relatively constant for any group of propagation zones. Therefore, one sensor package can be used to control multiple zones of misting. Each zone may contain a different type of plant at a different stage of growth, but the controller can control many zones independently relative to the "universal sensors".

The most important of these stress agents is light, followed by high temperatures. Relative humidity and wind as stress agents have a larger effect on outdoor propagation than on controlled-environment propagation where they are more constant.

Computer controllers can provide excellent control based on the "universal stress sensors" or with direct sensors for specific applications. These computer controllers also have the analytical capabilities to utilize new control methods like saturation vapor pressure deficit control, which may replace relative humidity control for fog applications. Record keeping, future expansion, new sensors and growing methods are additional reasons for large propagators to consider the large investment for computer controllers. Many propagators do not have the budget available to invest in a computer controller and yet still need better control than is possible with timers.

A controller that uses light and temperature in combination with a timed mist on interval can provide excellent control that approximates ideal control. This controller can be economical to buy and will require very little maintenance. Light- and temperature-sensitive mist controllers provide for excellent mist control at a cost only slightly higher than time clocks. These controllers save valuable time for the propagator who no longer has to readjust the time interval several times a day or live with lower stands and less growth.

There are many excellent mist controllers presently available. We are preparing a listing of most of the readily available controllers. This listing will provide easy to follow comparisons among controllers and will detail most features and benefits. These comparisons with manufacturers' prices will provide a controller selection reference to guide you to the controllers that will best serve your needs. This "Controller Selection Reference" can be requested by writing to me, Bruce Moesel at the following address:

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THE USE OF HUMIDIFAN IN PROPAGATION

DANIEL C. MILBOCKER

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Research was begun in 1974 at the Hampton Roads Agricultural Experiment Station to minimize or eliminate the weaknesses found within accepted propagation practices. Eliminating the application of excess water and its resultant soaking and cooling of the propagation medium was the primary objective of this research. The result was the introduction of ventilated high humidity propagation.

THE CONCEPT OF VENTILATED HIGH HUMIDITY PROPAGATION

Ventilated high humidity propagation is a method of propagation in which cuttings are maintained under controlled temperature and humidity. Temperature is maintained at a determined point by controlling the amount of solar-heated air that is exhausted.

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Ventilated high humidity propagation is a method of propagation in which cuttings are maintained under controlled temperature and humidity. Temperature is maintained at a determined point by controlling the amount of solar-heated air that is exhausted.

Humidity is maintained as close to 100 percent as possible by humidifying all incoming air. This method differs from non-ventilated high humidity propagation by having a means of controlling the temperature without lowering the humidity. It differs from misting by directly humidifying the air around the cutting instead of wetting leaf surfaces. Temperature and humidity control reduces the stress on cutting that occurs during intervals of high temperature or low humidity. Ventilated high humidity propagation requires the consideration of four factors on which it depends: 1) ambient air temperature and relative humidity, 2) humidification rate of incoming air, 3) rate of air exchange, and 4) air exchange among cuttings.

Ambient air temperature and relative humidity. Relative humidity is the amount of humidity relative to the maximum amount that air can hold at its existing temperature and pressure. Ambient air always carries some moisture. When ambient air is expanded by daytime solar heating, its moisture-carrying capacity is increased while the amount of moisture that it carries remains the same and relative humidity is decreased. When night air is cooled, it conversely contracts and is capable of carrying less moisture. The moisture it carries then becomes a larger percentage of its total capacity (increased relative humidity). If the percentage exceeds 100, the extra moisture condenses as dew. The temperature at that time is defined as its dewpoint. Therefore, humidifiers are not needed when the ambient air is near its dewpoint or during the night except during periods with unusual hot night winds.

Humidification of incoming air. Humidification occurs whenever unsaturated air comes into contact with water. Exposed water surface area is increased by dividing water into a multitude of fog-sized droplets of less than 50 microns in size. The duration of exposure is extended by carrying these droplets on an air current. Evaporation further reduces droplet size until the droplets remain airborne even in slowly moving air.

Droplets suspended in an airflow are unstable. They are produced by high-velocity movement and are subject to collision and uniting to form larger droplets until their speed is reduced. During cool weather droplets remain heavy longer which also increases their chances of collision. Larger droplets produced by collisions quickly settle and wet the cuttings. While some settling causes no problem, excessive settling should be avoided by reducing the water flow rate to the humidifier.

Technically, 10 to 20 gallons of water are required per hour to humidify each 1000 square feet of area. The smaller amount is adequate during cool weather and when the greenhouse is heavily shaded; 50 to 70% shading reduces the amount of heat generated during the summer season to manageable levels and still allows ample light for the cuttings. Heat reduction is necessary during the summer season but is not always advised for the winter season. During cool weather, ventilation may be stopped to reduce heat losses, but humidifiers must remain in operation at low rates to replace the moisture that condenses on greenhouse walls. Condensation can be reduced by using low humidification rates and by removing greenhouse shading to increase solar heating so that exhaust fans will operate.

Rate of air exchange. Solar radiation will heat a greenhouse 8 to 15°F higher than the outside air. The increase in temperature is higher during the summer season than it should be for growing plants. To cool a greenhouse effectively with a fan, the interior air must be exchanged approximately once per minute.

Humidification equipment cannot humidify completely at the rate of air exchange necessary for cooling. A greenhouse with 3000 square feet of floor space would contain approximately 35,000 cubic feet of air. An exhaust fan for humidifiers capable of humidifying 7000 cubic feet of air per minute would exchange the air once each five minutes. The cooling from evaporation during humidification combined with exhausting of hot air is adequate to cool the cuttings of a shaded greenhouse.

Shading reduces light intensity so that less heat is produced for the ventilation system to remove. Shading also moderates the temperature so that less readjustment of the humidification rate is required. The minimum amount of light needed for propagation is not well defined, but reduction of rooting has not been observed with as much as 80% shading.

Temperatures favorable for root initiation are not well defined. In general, increases in temperature favor root growth. Most species tend to tolerate temperatures below 90°F except poinsettia, cotoneaster, and pyracantha. These require slightly lower temperatures and show high-temperature damage as a buff color and brittleness of any new roots that do develop.

During cooler weather, a high rate of air exchange is not necessary and, if it is not lowered, excessive cooling will reduce root initiation. The exhaust fan should be thermostatically controlled so that it will not operate during cool and cloudy weather. Temperatures of the propagation medium will remain more favorable for rooting even when the humidifiers remain in operation.

Air exchange among cuttings. The most frequent failure in high humidity propagation is moisture stress resulting in leaf drop. It was common before mist and can be seen whenever humidification is not properly used. Humidification systems that do not provide for adequate circulation of humidified air among the cuttings function poorly because of the nature of solar radiation. The humidity is lowered by expansion of the heated air, which causes cuttings to wilt and leaves eventually to drop.

Ventilated high humidity propagation is successful only when circulation of air among the cuttings is adequate for removing heat generated from sunlight. Ordinary circulation fans move air at approximately 12 miles per hour and are inadequate for moving air the distance required for propagation. Increasing the humidified air flow to 30 miles per hour increases its effective circulation distance to approximately 35 feet.

By slowly oscillating the humidifier in a horizontal arc over the cuttings, the humidified area is greatly increased. Since air movement for ventilation moves from one end of the greenhouse to the other, the arc of oscillation is more effective if it does not circulate against the ventilation airflow. Humidifiers placed at the edge of the greenhouse efficiently circulate over 90 degrees and, when placed at a distance from the edge, 180 degrees.

In the most advantageous positions, one humidifier is capable of circulating humid air over approximately 1000 square feet of floor space. Under heavy shading or during cold season, circulation of humid air among cuttings does not need to be as thorough. The area capable of humidification by one humidifier is less clearly defined, but may be extended to twice or three times this area.

A HUMIDIFIER FOR VENTILATED HIGH HUMIDITY PROPAGATION

When this research was started in 1974, satisfactory humidifiers for propagation were not available. During 1978, research was begun to develop a satisfactory humidifier for ventilated high humidity propagation. The resulting humidifier is the Humidifan (Figure 1).

Humidifan is a high-capacity humidifier designed for efficient and dependable operation. It disperses as much as 40 gallons of water per hour as fog in an airflow that is essentially laminar, the type best suited for carrying water dispersed as fog-sized droplets. An oscillator directs this flow in an arc, which is adjustable up to 360 degrees and is capable of covering at least 1000 square feet of area when properly located.

There are three requirements for setting up ventilated high humidity propagation:

1. a fan-ventilated greenhouse
2. greenhouse shading
3. Humidifans

Ventilated high humidity propagation is a new concept based on a limited amount of research. While it has been used successfully under a variety of conditions, some conditions remain that have been untried. An efficient and common nursery greenhouse is the 30-by-100 foot plastic-covered quonset greenhouse. Ventilated high humidity propagation is easily set up in this type of greenhouse.

The fan-ventilated greenhouse. The rate of air exchange must be reduced to match the humidification rate more closely. Either a

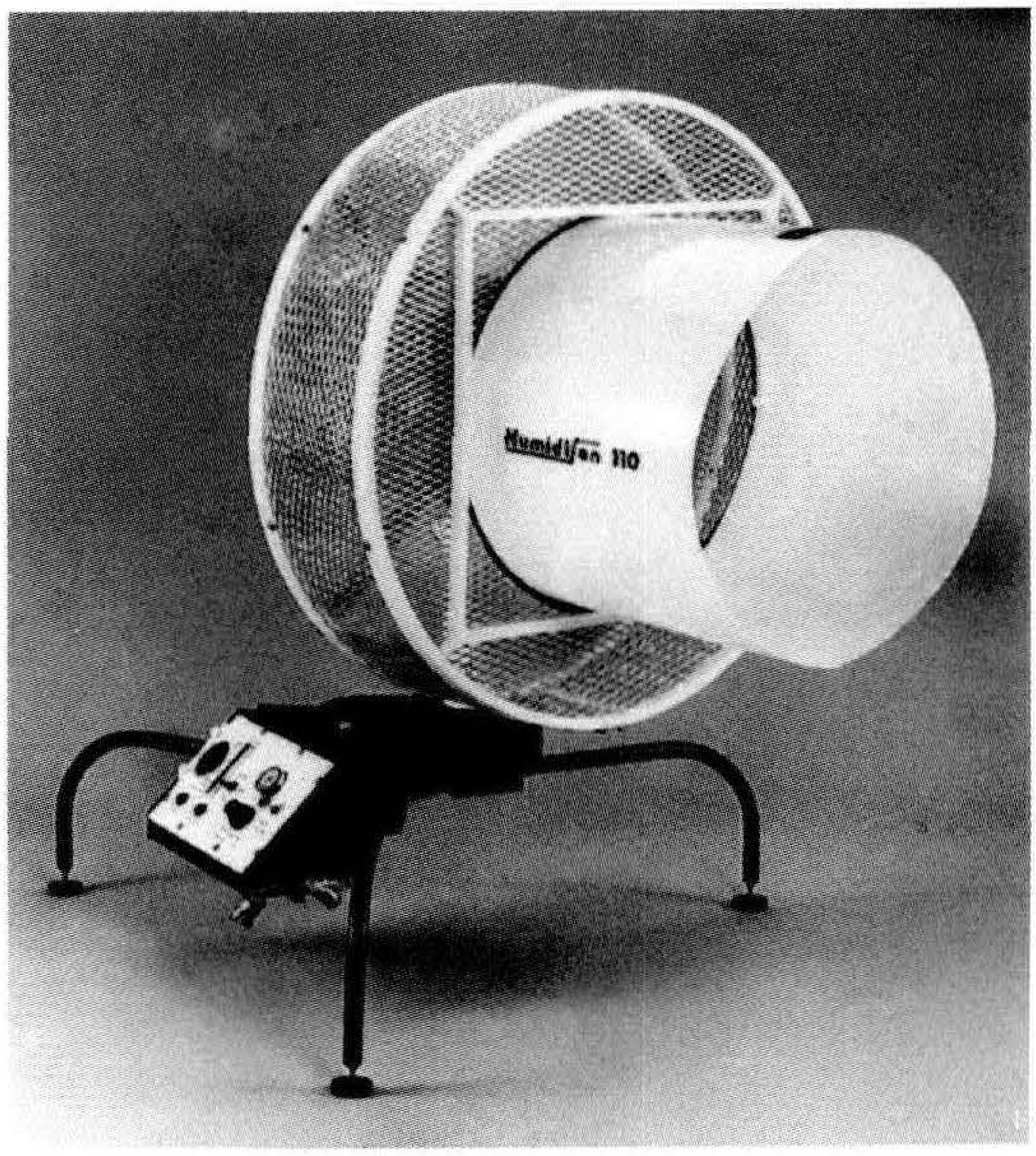

Figure 1. The Humidifan is designed specifically for ventilated high humidity propagation.

small fan capable of exhausting approximately 7000 cubic feet of air per minute can be installed or an existing fan can be partially blocked to allow only this amount of air to be drawn through it.

Shading of the propagation greenhouse. Fifty to 70 percent shading material has been used to reduce midsummer solar radiation. The area near the wall is difficult to humidify, therefore shading should extend to the ground level to minimize problems in this area.

Installing Humidifans in the greenhouse. Humidifans can be located in two patterns for propagating within the entire area of a 30-by-100 foot greenhouse. One pattern is to locate Humidifans at 33-foot intervals along the centerline of the greenhouse starting at the intake vent (doorway at the opposite end of the exhaust fan). Fans are operated in a 180-degree arc. The other pattern is to locate Humidifans at 33-foot intervals on alternate sides from each other beginning at an intake-vented corner. In this pattern, Humidifans are operated in 90-degree arcs. In all positions Humidifans should discharge their air flows in the direction of ventilation or not more than 90 degrees away from it. During midsummer these patterns will provide the best results.

Under heavy shading, during cool weather, or when propagating relatively hard cuttings, the range of coverage can be extended considerably. A compromise is to extend the range of the fans to 50 feet by increasing flow rate. However, the overloading increases the wetting near the humidifier.

Ventilated high humidity propagation is a new method of propagation that is proving to be both reliable and versatile. It offers a good alternative method of propagating that will develop cuttings into vigorous and healthy plants.

COMPUTER CONTROL OF IRRIGATION SYSTEMS

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Irrigation is for the purpose of maintaining an adequate water supply within the active root zone. In order to maintain the soil water system within acceptable bounds it is first necessary to estimate the present state of the soil-water system. The estimation may be made indirectly by maintaining a budget of available water or directly by measuring soil-water content distribution or a closely related variable (4). Changes in the state of the system are made by manipulating the irrigation system so that water is applied at the proper time and in the proper quantity as established by some irrigation management policy.

The objective of this work was to develop a digital computer control system (DCCS) as an aid for irrigation system management such that: 1) its cost is of the order of magnitude of a low-cost microcomputer; 2) all system components are readily available from local outlets, or they are low cost so that they can be kept in stock; and 3) the system operates in manual, timer, and direct digital-control modes. The system should be simple to operate and flexible in order to meet the demands of a controlled production system.

DIGITAL COMPUTER CONTROL SYSTEM

Hardware components. A block diagram of the components of a DCCS system are shown in Figure 1. At one end is the soil system and at the other is the computer system. The computer system acquires information about the soil system through an analog front end, here exemplified by a single sensor. Acquired data is processed by the computer system, and any necessary actions are carried out through an output subsystem, here exemplified by a single-controlled solenoid valve.

A DCCS was developed based on a low-cost home computer using readily-available components for both the analog front end and the output subsystem (7). The characteristics of each component are the following:

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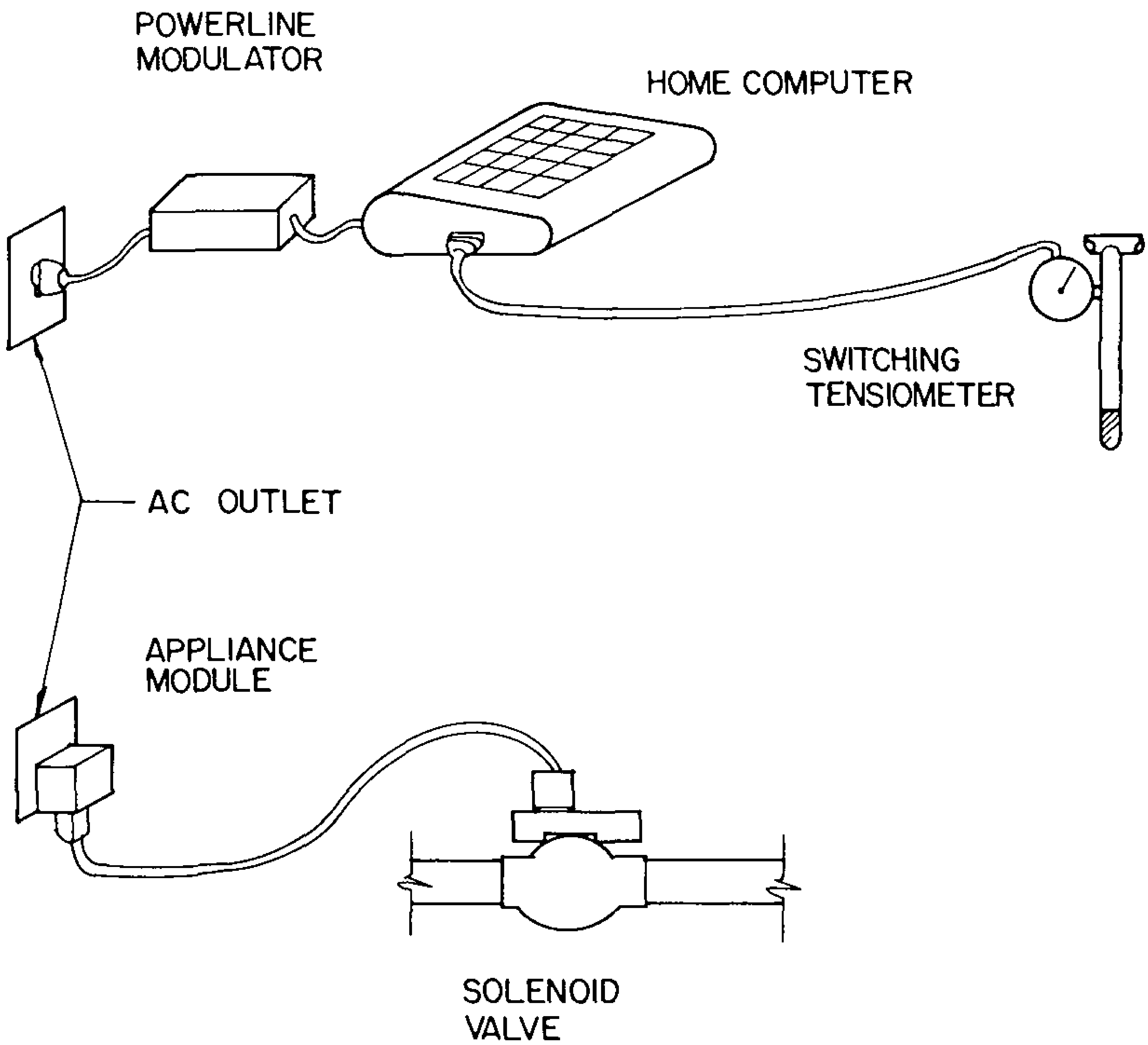

Figure 1. Elements of the digital computer control system.

1) **Microcomputer.** Low-end home computer with joystick and paddle ports. This type of computer was used to take advantage of its low price, availability and widespread available support.

2) **Output subsystem.** Because of the characteristics of irrigation systems, the output subsystem needs only to control discrete devices such as solenoid valves or pumps that control the flow of water and fertilizer. The control device used here was a power-line modulator circuit (PLMC) with a receiver module for each device to be controlled.

This type of system uses the AC wiring line to encode a high-frequency signal that is received by the modules which, in turn, react to commands encoded in the signal. Since the AC wiring is used to transmit the signals, this system has the added advantage that no additional wiring is required for control signals. The use of a power-line modulator imposes two restrictions on the system. First, the maximum number of devices that can be controlled is 256 and second, the time required to transmit and execute a signal to change the state of a device is about 2.5 seconds.

3) **Analog front end.** Each joystick port of the microcomputer

provides five discrete inputs, and each paddle port provides an analog-digital (A/D) port, typically with eight-bit resolution. Although it has been shown that control of irrigation systems can be attained using a small number of sensors (3), systems or management procedures requiring a large number of sensors can be accommodated at a relatively low cost by using multiplexers. An example is the system developed by Stone *et al.* (6).

A list of the components used is given in Table 1. All components are available from department stores, consumer electronics outlets, or mail order. Also, no single device, including the computer, costs more than $100.

Table 1. Components used in the field implementation of the DCCS[1].

Microcomputer system	C-64, disk drive and monitor.
Power line encoder	X10 Powerline modulator.
Receiver modules	Radio Shack appliance module.
Discrete sensors	Switching tensiometer.

[1]Mention of trade names does not imply endorsement by the authors.

Software component. The software allows the user of the computer system, in this case the irrigation-system manager, to use the computer in three different control modes: manual, timer and automatic.

1) **Manual control mode.** In manual operation the user controls the irrigation system from the DCCS terminal. This mode is necessary to provide the user with a manual override of the other modes as well as the necessary utility to test newly-installed equipment.

2) **Timer control mode.** In this mode the DCCS acts as a timer and executes commands from a user-created schedule. A variation of this mode that consists of specifying cycled applications was included. This accommodates systems in which high-frequency applications are necessary, such as mister systems in greenhouse propagation houses. The timer mode is used mainly when watering frequency and amounts are decided externally from the computer. This is the case when irrigation is based on visible plant stress, estimations of water use from pan evaporation, or the operator's opinion. In this mode the control loop is open since no data are acquired at any time about the state of the system.

3) **Automatic control mode.** In this mode data about the state of the system are acquired through the analog front end of the DCCS and are used as inputs to a control algorithm. Control algorithms based on real time data have been presented in the literature (3, 5). The DCCS developed here uses a moisture threshold sensor consisting of a tensiometer and an optoisolator as described by Zazueta (7). The tensiometer and optoisolator can be replaced by any other device that produces a TTL signal. Moreover, if the distance to the sensor is small, the sensors can be directly connected to the joystick

ports of the computer. Alternatively, when a switching tensiometer is used, the magnetic switch may be used to interrupt power to the solenoid valve unless irrigation is required.

Software is available from the IFAS Computer Support Office, Building 120, University of Florida, Gainesville, Florida 32611.

FIELD EXPERIENCE

Computer-controlled systems using the hardware and software described here have been installed at many location in Florida, including extension demonstrations, greenhouses, mist houses, field nurseries, citrus and blueberries. The DCCS can be installed by any individual familiar with electrical installation procedures and with minimal computer skills.

Labor savings related to irrigation activities have been significant in field installation. A benchmark system was used to compare irrigation controlled manually and by computer. With the computer-controlled system the time required in irrigation-related activities was reduced to 12 percent of the original time used and water use was cut to 34 percent of the water use before the system was installed. Also, irrigation is now scheduled in such a way that there is minimum interference with other activities in the greenhouses or in the field (2).

It has been demonstrated that it is practical and economical to use low-cost home computers as irrigation-system controllers. The availability of these computers and supporting hardware, as well as their low cost, make them very practical for agriculture production systems. Furthermore, these small computer systems provide flexibility and low-cost expansion capability, which cannot be achieved with other types of control systems such as timers, dedicated microprocessors, or higher-level computers.

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UNIFORMITY ANALYSIS OF VARIOUS TYPES OF MIST PROPAGATION NOZZLES

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Abstract: Fourteen different types of nozzles were evaluated for mist propagation. Spacing recommendations are presented for 85 percent or better coefficient of uniformity under the nozzle. Growers can take this information to construct their own mist propagation beds.

REVIEW OF LITERATURE

Today several different types of mist nozzles are available for propagation. Stoltz *et al.* (2) evaluated 10 different types of nozzles used in propagation at that time. They expressed the common problem of wear, which results in larger particle size and increased flow rate. Since then a new line of durable hard-plastic nozzles has been introduced. The hard-plastic nozzles are less expensive and will not wear as fast as metal ones. Sumner and Gibson (3) evaluated seven nozzles used in mist propagation. Four were of durable plastic. Their findings indicate that these durable-plastic nozzles are fairly uniform for spacings tested.

MATERIALS AND METHODS

Fourteen different types of nozzles were tested. Table 1 lists nozzle types and their description. The information in parenthesis denotes nozzle orifice size (large to small). Nozzles were evaluated for uniformity by collecting water in one fluid-ounce containers in a straight line spaced at 6 in. intervals with the first located 6 in. from the nozzle. The nozzles were all mounted on 18 in. risers along with a pressure gauge to determine the pressure at the nozzle. Water collected in each container was then measured. Data was collected at pressure settings of 20, 40, and 60 psi. Droplet particle size was estimated by using water-sensitive paper. Droplets were measured with a hand lens using a known scale.

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Table 1. Types of mist nozzles evaluated.

Number	Description	Type
1	Dramm Nifty (brown)	Deflection
2	Dramm Perfect (blue, grey)	Deflection
3	Eddy Mist	Deflection
4	Floral Mist (0.031, 0.020)	Deflection
5	Microjet (white, green, black)	Deflection
6	Naan 7102 Mister (white, green, black)	Deflection
7	Naan 7102 Mini Sprinkler (white, green, black)	Rotating
8	Rainbird Micro-Bird Spinner (orange, green, black)	Rotating
9	Rainbird Micro-Mister (orange, green, black)	Deflection
10	Rainbird CPR Series 360° (spray nozzle #4)	Deflection
11	Roberts Spot-Spinner (avocado)	Rotating
12	Roberts Spinner-Sprinkler (nozzle #2)	Rotating
13	Solcor 8000 HP Micro-Dan Sprinkler (blue, grey, violet)	Rotating
14	Solcor 7000C Micro-Dan Sprayer (blue, grey, violet)	Deflection

Data collected on nozzles' discharge uniformity was used to determine appropriate spacing of nozzles at that particular pressure setting. A uniformity coefficient (CU) was used (1) to give a numerical expression to serve as an index of the uniformity. This expression is defined by the equation:

$$CU = 100 \times (1.0 - \frac{X}{m \times n})$$

in which **X** is the deviation of individual observations from the mean value **m,** and **n** is the number of observations from the mean value. An absolutely uniform application is then represented by a uniformity coefficient of 100%, a less uniform application by some lower percentage.

RESULTS

On the days data was collected, temperatures ranged from 85 to 105°F. All nozzles were tested in enclosed environment. This alleviated the problem of excessive drift of mist due to wind.

Table 2 presents the recommended spacing, spray diameter, and uniformity coefficient for the nozzles tested. Uniformity coefficient was calculated for several spacings of each nozzle. The spacing of nozzles was determined for a CU starting at 85%. Any spacing less than the stated spacing will give a better uniformity coefficient. The spray diameter was the diameter of mist pattern collected. It is recommended that bed width should be at least 60 to 70% of spray diameter.

Table 2. Recommended spacing and spray diameters for nozzles.

Nozzle	Pressure (psi)	Spacing (ft)	Spray Diameter (ft)	CU (%)
Dramm				
Nifty (brown)	60	4.5	12.0	90.0
	40	4.0	11.0	90.7
	20	3.0	9.0	88.6
Perfect (blue)	60	6.0	24.0	89.5
	40	5.0	22.0	91.3
	20	4.0	17.0	88.3
Perfect (gray)	60	6.0	17.0	91.1
	40	3.5	12.0	87.6
	20	3.5	14.0	87.4
Eddy Mist	60	4.5	14.0	89.2
	40	4.0	13.0	90.0
	20	3.0	12.0	91.5
Floral mist (.031)	60	2.5	8.0	92.2
	40	2.5	5.0	90.0
	20	2.5	5.0	89.0
Floral mist (.020)	60	2.5	6.0	89.0
	40	2.5	6.0	88.7
	20	1.5	5.0	99.0
Microjet (white)	60	4.5	19.0	93.4
	40	4.0	17.0	90.1
	20	3.5	15.0	86.5
Microjet (green)	60	3.5	12.0	86.7
	40	2.5	11.0	91.2
	20	2.0	10.0	96.0
Microjet (black)	60	3.0	8.0	89.2
	40	2.5	8.0	85.5
	20	2.0	7.0	92.0
Naan				
7102 Mister (white)	60	4.5	16.0	87.4
	40	5.0	15.0	95.2
	20	4.0	13.0	87.0
7102 Mister (green)	60	4.0	12.0	90.4
	40	3.5	11.0	91.5
	20	3.0	9.0	96.4
7102 Mister (black)	60	3.5	14.0	92.6
	40	3.0	13.0	91.8
	20	3.5	12.0	99.3
7102 Mini Sprinkler (white)	60	10.0	27.0	83.0
	40	9.5	27.0	81.0
	20	6.0	26.0	83.0
7102 Mini Sprinkler (green)	60	9.0	26.0	79.8
	40	9.0	25.0	85.6
	20	6.5	24.0	87.4
7102 Mini Sprinkler (black)	60	6.5	23.0	77.5
	40	7.0	22.0	70.0
	20	6.0	19.0	53.0

Nozzle	Pressure (psi)	Spacing (ft)	Spray Diameter (ft)	CU (%)
Rainbird				
Micro-Bird Spinner	60	9.0	25.0	87.0
(orange)	40	10.0	27.0	90.4
	20	9.5	28.0	89.4
Micro-Bird Spinner	60	7.5	22.0	88.9
(green)	40	6.5	21.0	88.8
	20	5.0	21.0	93.0
Micro-Bird Spinner	40	5.0	12.0	90.4
(black)	40	5.0	11.0	90.0
	20	3.0	6.0	96.8
Micro-Bird Mister	60	3.0	18.0	89.9
(orange)	40	4.5	16.0	86.7
	20	4.0	13.0	90.6
Micro-Bird Mister	60	4.0	13.0	85.6
(green)	40	3.5	13.0	84.4
	20	3.0	11.0	89.6
Micro-Bird Mister	60	3.0	10.0	89.7
(black)	40	2.0	10.0	87.6
	20	2.5	8.0	97.6
CPR Series 360°	60	5.0	17.0	93.3
Spray Nozzle (#4)	40	4.0	16.0	84.0
	20	7.0	16.0	84.3
Roberts				
Spot-Spinner	60	4.0	21.0	89.2
(Avocado)	40	3.5	22.0	88.6
	20	2.5	24.0	58.0
Spinner-Sprinkler	60	5.0	23.0	90.4
(No. 2 Nozzle)	40	5.0	23.0	88.3
	20	8.0	25.0	91.1
Solcor				
8000HP Micro-Dan	60	15.0	34.0	85.8
Sprinkler (blue)	40	17.0	34.0	91.7
8000HP Micro-Dan	60	10.5	25.0	88.5
Sprinkler (grey)	40	8.0	24.0	88.7
8000HP Micro-Dan	60	6.0	21.0	83.1
Sprinkler (violet)	40	6.0	20.0	70.5
7000C Micro-Dan	60	4.5	19.0	89.8
Sprayer (blue)	40	3.5	18.0	92.8
7000C Micro-Dan	60	3.5	12.0	88.7
Sprayer (violet)	40	2.5	10.0	81.9
7000C Micro-Dan	60	3.5	12.0	88.7
Sprayer (grey)	40	3.0	11.0	90.1

A mist is defined as a droplet size of 50 to 100 microns. A fine drizzle is classified as a droplet size of 80 to 150 microns. For propagation, a particle size of 50 to 150 microns is desirable. Data for each of the nozzles tested, giving the droplet size range (microns), and the majority of droplets produced by the nozzle at the stated pressure, is available from the author.

DISCUSSION

All nozzles except Rainbird Micro-Bird Spinner, Rainbird CPR Series 360°, and Roberts Spot-Spinner produce acceptable particle size and distribution. These nozzles would be appropriate for irrigation only. The Dramm Nifty (brown), Eddy Mist, Microjet (white), Naan 7102 Mister, and Solcor 7000C Micro Dan sprayer performed exceptionally well at around 40 psi. The Rainbird Micro-Bird Mister (orange, green) and Roberts Spinner-Sprinkler (No. 2) also gave good results at a higher pressure of 60 psi. All other nozzles would be appropriate for mist propagation with spacing recommended.

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MASS PRODUCTION OF TREES IN GRO-BAGS

BILL REESE

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Box 5189
Ocala, Florida 32678

Thorobred Trees produces trees in root-control, field-grow containers on approximately 100 acres in north central Florida. We have been container growers of plants and small trees for 13 years. For the last three years, we have planted approximately 80,000 trees in Gro-bags, 14-, 18-, and 24-inch. We are growing around 35 cultivars of trees for landscape use in the southeastern United States.

Early in 1983 after hearing Dr. Carl Whitcomb present a program on field growing in root-control containers, we decided to try some for ourselves. We planted 1200 trees in 14- and 16-in. Gro-bags. We planted some in our potting soil mix consisting of pine bark, native peat, and coarse sand; some in a blend of potting soil and native sand, and the majority in just native sand. In the first winter the 1983 Christmas freeze devastated about 30% of our container stock, but we had no damage or loss in our bag tree area. The trees planted in native sand grew off much better than the others.

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Thorobred Trees produces trees in root-control, field-grow containers on approximately 100 acres in north central Florida. We have been container growers of plants and small trees for 13 years. For the last three years, we have planted approximately 80,000 trees in Gro-bags, 14-, 18-, and 24-inch. We are growing around 35 cultivars of trees for landscape use in the southeastern United States.

Early in 1983 after hearing Dr. Carl Whitcomb present a program on field growing in root-control containers, we decided to try some for ourselves. We planted 1200 trees in 14- and 16-in. Gro-bags. We planted some in our potting soil mix consisting of pine bark, native peat, and coarse sand; some in a blend of potting soil and native sand, and the majority in just native sand. In the first winter the 1983 Christmas freeze devastated about 30% of our container stock, but we had no damage or loss in our bag tree area. The trees planted in native sand grew off much better than the others.

Within 18 months the one-gallon size trees we had planted were reaching heights of between 10 and 16 ft. and calipers up to 3 in. The species we tried were sycamore, Chinese tallow, photinia, red maple, live oak, slash pine, dogwood, magnolia, crape myrtle, East Palatka holly, and laurel oak.

After this initial good experience we started planning our first major crop in August, 1985, and planted over 80,000 trees in the 18 months that followed. After the hard freeze in 1983 and 1985 thousands of acres of citrus production land in north central Florida became available for alternative production use. It is on this former citrus land that we are growing our trees in field-grow containers. The soil in our area is sandy and very well-drained. This type of soil has never been preferred for field growing and ball and burlapping of trees.

Our program on production consists of taking bare-root liners, 1-, 2- and some 3-gal. tree stock, and putting it into 14-, 18- and 24-inch Gro-bags. We planted weeping willow, 'Bradford' and 'Aristocrat' pear, bald cypress, live oak, photinia, green ash, slash and loblolly pine, wax myrtle, crape myrtle, East Palatka holly, Chinese tallow, Shumard oak, Savannah holly, Drake elm, river birch, Chinese pistache, Nellie Stevens holly, magnolia, ligustrum, red maple, redbud, dogwood, sycamore, and podocarpus.

Our soil pH is amended to between 5.5 and 6.5. We set our planting rows as follows: 14-in. bags are six feet apart and six feet on the row in groups of four rows to a section, with a 10-foot road between sections. Our 18-in. bags are set in rows 7 ft. apart with trees spaced 7 ft. down the rows. With 24-in. bags, rows are 7 ft. apart and 8 ft. down the row. We use the "Holofil Planter" to plant our bags in the field.

A four-man crew is used and we have a piecework incentive pay plan for planting. Our four-man crew is paid $4.00 per hour plus five cents per unit per man for all units over 600 planted in an eight-hour day. This rate will produce a cost of 21 cents per bag planting cost. This does not include putting the trees in the bags.

After bags are in the field, we finish putting in our irrigation lines. Our irrigation systems are Roberts Spitters and micro-jet emitters into black poly tubes which are laid along each row. We apply 3/10 in. of water daily. No overhead irrigation is used in our growing areas.

We apply 350 pounds of nitrogen per acre per year with six applications of 16-4-8 beginning in March through October. Our herbicide program consists of Surflan applied every 10 weeks for preemergence and Round-Up and paraquat for postemergence treatment. We spray pesticides on an as-needed basis only.

Harvesting presents interesting opportunities as no specialized equipment for Gro-bags has been developed at this time. We hand dig as well as use a Bobcat with a forklift to harvest. Upon harvesting we immediately put all trees into a holding area for a designated period of time to acclimate them for shipping and installation in a landscape site. On some trees we remove the bag and containerize into larger rigid containers.

This is a walk through our production. There are, of course, advantages and disadvantages to using Gro-bags. Producing trees in Gro-bags has afforded growers in central Florida the opportunity to grow in the field in our sandy soil conditions. The Gro-bag does an excellent job of root pruning. This is the first advantage. Trees in Gro-bags have massive fibrous root system. Approximately 80% of the root system is contained in the Gro-bag. The Gro-bag has panels that allow small roots to pass through but restricts the root at the point it leaves the bag. The massive network of feeding roots accelerates the growth of the tree.

The second advantage comes from the increased caliper development and head growth that results from a Gro-bag tree's massive feeder-root system. The third advantage is the compact size of the rootball in relation to the tree size, which makes transporting and transplanting much easier. The fourth and most dramatic advantage is the ability of the Gro-bag tree to establish itself immediately in the landscape setting. When the bag is removed, the stored energy in the restricted root zone promotes new root growth at once. This new growth comes from the many roots that have been root pruned by the Gro-bag. The tree establishes much quicker and there is no need to do major pruning at the new site. Finally, the ability to grow, move, and establish the Gro-bag tree gives the producer in central Florida a higher-quality product to market.

The disadvantages of using Gro-bags include a larger upfront cost in planting as opposed to regular field growing. Also, there is not any specialized harvesting equipment available at this time. A third disadvantage comes from the nonrigid makeup of a container. The cosmetic appearance of the bag is less desirable than that of a rigid container.

After looking at all of these advantages and disadvantages, I feel strongly that under our growing conditions the Gro-bag will definitely help us produce high-quality trees at a profit.

PROS VS. CONS IN USING ROOT-CONTROL FIELD-GROW CONTAINERS

KENT LANGLINAIS

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During the Southern Nurserymen's Association convention in Atlanta, in August, 1983, Dr. Carl Whitcomb came over to my booth in the exhibit hall and began talking about a system of growing that I had never heard of before. The more he talked, the more interested I became. He took me over to his booth, introduced me to Mr. Ralph Reiger and the root control bag. He had a tree growing in this fabric bag. Realizing the need and importance of this new system, I made the remark, "Where have you been all these years?"

PROS

The first advantage is that the trees will not blow over in a strong wind as would large trees in containers, which must be tied and staked. Trees in field-grown containers have withstood winds in excess of 80 miles per hour without any damage to the trees.

The second advantage is that it takes less water to grow in these root control bags than in large containers. Plants in the root control bags need no more water to grow than they would in a field operation. A drip irrigation system would help grow a faster crop. However, in a high-rainfall area, it is not necessary. We receive 60 inches of rain per year, and do not need irrigation.

The third advantage: There are no wrapping roots, as in container-grown trees. The inner surface of the fabric is "bearded"; that is, there are loose fibers on the surface of the fabric. These fibers prevent root circling by entangling the root tips, forcing them to grow through the container wall. Since the root is very small at this point, there is little or no restriction by the fabric. As the root grows farther into the surrounding soil and increases in density, the fabric begins to constrict or girdle the root. Unlike container-grown trees with circling roots that would need to be cut before planting, root-control bags are continuously pruning the roots and making a better root system.

The fourth advantage is protection from freeze damage. Container-grown trees must be unstaked and jammed together to protect them from the winter elements, then spaced and staked again in the spring. In addition, some trees must be brought inside, and others need windbreaks to protect them, which creates more work. The roots in the root control bags are below ground level and are protected from freeze damage just as in a field operation.

Advantage five is the ease of digging or pulling them out of the ground. The normal balled-and-burlapped method has a larger root system that has to be cut, plus the digger has to be careful in shaping the ball so that it will not crack or fall apart. In some areas, especially those with high levels of sand, the balled-and-burlapped tree is almost impossible to dig. In our area, sometimes it is too wet to dig trees. Trees grown using the root-control method can be dug at anytime, with much more ease and more quickly. There are mainly small feeder roots and the fabric in the ground serves as a guide for digging. Sometimes a root will escape through the area where the bag is seamed together. These are mainly anchor roots that can easily be cut without affecting the livability of the trees. With the new bags that have glued bottoms and sewn seams, there is very little area where roots can escape.

The sixth advantage is that the plants can be dug anytime. Since there are more feeder roots that are not cut or disturbed while digging, there is a higher livability than with the balled-and-burlapped method. In the case of the balled-and-burlapped trees, the root systems after the ball is formed resemble one's hand with nubby roots and a small amount or no feeder roots to help the trees survive the shock of transplanting.

The seventh advantage is that the balls are smaller and lighter. According to the American Association of Nurserymen Standards, a 2-in. caliper tree would require a 24-in. ball, which would weigh approximately 275 lbs. It is recommended that a 2-in. caliper tree be grown in an 18-in. bag and should weigh approximately 175 lbs. More trees can be carried per truck load, making the freight per unit cheaper. It would take a machine to handle a 24-in. balled-and-burlapped tree while the 18-in. bag could be handled by hand. Since the bottoms of the root-control bags are flat and the same width of the bag, they are easier to stand up.

The fact that fewer roots are lost gives an advantage besides increased livability. It is estimated that approximately 75 to 85% of the root system in balled-and-burlapped trees is lost. The remaining roots are mainly anchor roots, which are then very important for the livability of the trees. With the bag method, just the opposite is true; about 85% of the root system is retained. The only roots that are cut are the ones that escape through the fabric.

Rapid establishment is the ninth advantage. Since there are hundreds of feeder roots in the bag that are not being disturbed, they continue growing undisturbed in their new setting. The fibrous root system created by the bag provides long-term benefits to tree health in addition to the obvious advantage of ease in transplanting and rapid establishment. The chances of root girdling and strangulation in bags is remote since water and nutrient absorption is accomplished by a mass of small roots as opposed to a few major roots. In addition, no roots from trees grown in the fabric container will ever get as large as when the same species are grown conventionally, which reduces the danger of damage to sidewalks, driveways, and foundations. The fibrous and compact root systems lend themselves readily to planting in pits and other landscape situations where horizontal root development is restricted. Anchorage should be equal to or better than conventional trees, since the many small roots act much like the many fine strands of steel in a cable versus a solid steel rod of the same diameter. Fabric container-grown trees that are transplanted and grown to a larger size would be better candidates for large trees to be moved easier.

Advantage ten: overall cost is lower. Even though the upfront cost to plant trees in field-grown containers is higher than the conventional method, the overall cost is much less. In digging the crop, less experienced help is needed since it is not necessary to sculpture the ball. Little or no burlap is used. The ball is lighter so manpower can be used in handling instead of machinery. Because of the size and weight of the finished product, more plants can be loaded on trucks; therefore, cost per unit is less.

These are just a few of the pros. There are no doubt many more than could be reported from different areas around the country or the world.

CONS

Certainly, the initial cost of around $1.00 to $2.60 per unit, depending on the size of the container used is a con. This does take a large investment when planting several thousand trees. However, remember that at digging time, a great deal of this cost will be balanced off by less labor and burlap.

Another con would be that at some time in the future, the root control fabric must be removed or the tree becomes a bonsai or dies. The fabric does not rot and only light will cause the material to deteriorate. Therefore, if the market is slow and trees do not sell on the market, some trees will out-grow the bags.

This con could be turned into a pro with the root control bag, but not so easily with the conventional ball-and-burlap method. If a crop does not move in a bag, it can easily be dug and sold to a container operation as a super liner for larger can production or large field-grown trees.

These are just two facts that we consider cons. Others may appear in the future as more bags are used in the industry.

A key factor to remember is that it is not the quantity of soil moved, but what is in the soil that is important. In the future, when history is written about the wholesale nursery field operation, this root-control type container will be one of the tools highly mentioned as having helped revolutionize the nursery industry.

EXPERIENCES IN GROWING AND MARKETING TREES AND SHRUBS IN GROW-BAGS

BUCK JONES

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For 15 years my business has operated from a location in Gwinnett County, Georgia. This is about 30 miles northeast of Atlanta. The business is plant brokerage, plant, and sod distribution. We grow some plants we have not had in adequate supply or that need to be grown in or near our climate. This also evens out seasonal labor requirements and provides a method for keeping high-quality people employed.

We have to think WEATHER in everything we do in our area. Our winter temperatures have dropped as much as 70° to 80°F overnight and to lows of 8° to 12°F. The cold-damage risk is high when we have trees and shrubs that are unprotected. So we spend a lot of time and money on winter protection. Our annual dilemma is that our ideal stocking time is from February 15 through March 15. If we stock earlier, we worry about cold damage; if we stock later, growth is beginning. If it is too wet for growers to harvest during that 30 days, we may not get our orders. If we bring in plants from a warmer climate, we have to make sure the timing is right. The demand for trees and plants out of season has grown rapidly in the past 10 years.

My first mechanical harvesting experience was with a Jiffy Baller, and the lasting impression from that was, "there has got to be a better way."

When we learned about root control bags, we began to see them as a way to help solve many of our problems and offer some additional advantages as well:

1. Better inventory control by having more windows of harvest and, therefore, better utilization of space.
2. Less freeze damage by having a partial supply close by with root systems below ground and protected. These could be harvested quickly and in weather that might not allow hand or machine digging.
3. Improved display areas due to flat-bottomed balls that stand up better than cone-shaped balls.
4. More accessible product compared to a container that would also offer soil-to-soil rather than soil-medium to soil relationship. This, along with a good fibrous root system, should improve plant survival.
5. Plants would have adequate root balls with less weight to

transport and handle than conventional ball and burlap.

6. One big advantage to me is not having to have a 6- by 10-ft. access to each plant in order to harvest it. Every other tree can be harvested from a block and still leave the block full of quality trees for this season's harvest.

Three years ago we expanded our operation to our family farm near Augusta, Georgia, which is 120 miles east of our present location. Utilizing the equipment that we had, including cable-tow overhead irrigation, we installed 25,000 root-control bags in an intensive planting. This was repeated the last two years.

Planting and growing was accomplished pretty much as expected. This is like container production in that most of the cost is up front, so having replacement plants ready to go is important to make sure that you can utilize your investment. In some plantings we alternated bag sizes so that we could harvest every other plant and leave the rest to go to a larger size.

Root-control bag trees can be dug with a man on each side at the rate of one per two minutes. It takes a few more minutes to repair and lace the top before transporting. We have been able to harvest when temperatures were near 100°F with no plant damage.

The major problem that we have is roots escaping where the plastic bottom is sewn to the fabric. This has contributed to varying success with our summer digging. Basically plants with good root containment harvest well and those with poor containment harvest poorly. Plants that were pregrown in containers have better containment.

We are looking forward to trying the new-model bag with the plastic bottom glued in. We think this will solve the containment problem.

One important thing in marketing is to make sure that the root-control bag is removed when planting. We let our customers know with a computer-printed note on each invoice, a tag on each plant, and by a verbal reminder from each sales person. The procedure for removing the bag is on the tag and is pointed out by each sales person.

Which growing method is best? Each method has its advantages and disadvantages. The advantages that we see, in our infant stage of experience, make root-control bags a visible part of our future.

The customer will ultimately determine the success of this growing method based on his ability to profit from this product.

We feel that the method can be profitable to us, so we want to make sure the customer gets a quality product and understands how to remove the bag and plant profitably.

GROW-BAGS: ARE THEY ALL WE HAD HOPED FOR?

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The Titanic is unsinkable! Grow bags are wonderful! Some people may bet their lives or livelihood on these statements. We know what happened to the Titanic, and we are witnessing equally disastrous results for many on their maiden voyage with grow bags. No! Grow bags are not all we had hoped for.

POSITIVE FEATURES

One positive feature of the field grow bag is continuous root pruning without the growth retardation usually associated with mechanical root-pruning procedures. In our view, this is the ONLY *reason for using a grow bag.*

NEGATIVE FEATURES

Upfront investment. Planting requires extensive investment in time, labor, equipment, and bags at planting. Historically, a big advantage of field-planting over container-growing is the fact that little cost is expended prior to the time plants are sold. With grow bags this advantage is lost. And do not forget the interest on the money. There will be no immediate return on this investment.

Precision hand labor requirement. Planting too deeply, leaving an air pocket, not compacting the soil uniformly, punching a hole in the bag or ripping a stitch can and does cause problems that render the bags useless or cause roots to grow over or through the bag.

Difficult mechanical cultivation. Cultivation for weed control and relief of surface compaction of the soil is almost impossible without damaging the grow bag or covering it with soil, either of which will likely destroy the root-confining capabilities of the bag. Hand cultivation is expensive.

Difficult fertilizer application. For best effectiveness, fertilizers should be applied in the bag, and should be covered with soil. This also will require hand labor, until or unless specialized equipment is developed.

Harvesting problems. Harvesting is not as easy and simple nor as inexpensive as promotional literature implies. One escaped root can make harvesting as difficult as it would have been without the grow bag. A very high percentage of plants we have seen harvested has one or more large roots that had escaped the confinement of the bag.

Off-season harvesting of plants grown in bags requires almost the same attention as plants grown in the field without bags. Small roots that penetrate the bag apparently function quite well in water uptake. When they are removed at harvesting, plants become water stressed quickly. Due to the small soil-volume: top-growth ratio of harvested plants, frequent watering is essential even after plants are hardened off.

Plants in grow bags are similar to container-grown plants in that they must be harvested at a specific time or size. If not in grow bags, trees may be left to attain a larger, more valuable size when sales are slow.

Unattractive packaging. Grow bags rank higher on the UGLY scale than the rusty metal cans used in the early days of container growing. Additional burlap and pinning are required to confine soil in the bags for handling and shipping.

Bag removal. Grow bags must be completely removed when replanting. This is not an easy task with most plant species. We have seen bags slit vertically with a knife every 6 in. to reduce the power needed to rip the bag away from the roots. When the bag was completely removed the plant was bare-root. Others have used a knife to cut roots away from inside the bag after slitting the sides. This is expensive and frustrating for a landscape contractor, and our guess is that one of two things will happen. Either he will not remove the bag, or he will not buy plants grown in bags.

Stability after planting. Trees with large top growth and small root balls require extensive guying and staking to prevent blow over. This also is an added expense for the landscaper.

Confirmation to AAN standards. Most landscape architects use AAN Grades and Standards for specifications relating to tree caliper and ball size. Changes or additions to these standards to accommodate field grow bags probably will take several years. It will be necessary to determine the bag sizes required to develop a root ball that will support specific caliper trees. In the meantime, sales of plants produced in grow bags will not be used on many jobs designed by landscape architects. One of my good friends had an order for several 3- to 4-in. bald cypress, which specified a minimum 32-in. ball. He had some beautiful bald cypress of the proper caliper in 20-in. grow bags. Before the buyer would accept the plants, my friend had to place the bag-grown plant in a 32-in. wire basket and form a ball around it. How much profit do you suppose he made on that order? We should add that the buyer approved of the procedure as a way to meet the architect's specifications. But, what happens if the trees die or blow over in the landscape exposing the smaller rootball? Obviously, the integrity of both the contractor and the grower will be questioned.

OUR ADVICE

We advise our clients to root prune mechanically the best way they can and try a few, very few, grow bags on several plant species to observe for themselves. Do they perform well in your soil types? Do they dig easily? Can they be dug safely during the off-season? Will your clients buy them? How do costs compare with your present system?

Containerizing or boxing field-grown plants still are the best growing procedures for providing large trees for off-season sales. With proper care, most species can be harvested safely with a tree spade during the off-season, especially if they were root pruned at least one time after planting into the field.

SUMMARY

Grow bags are still in the early stages of development but are being promoted as a finished and proven growing and marketing system. We sincerely hope solutions to most of the many problems will be found before the "Grow Bag Ship" sinks so deeply that it cannot be refloated. At the present, grow bags are not all we had hoped for.

FUNGICIDES USED IN PROPAGATION AT FLOWERWOOD NURSERY

BUDDY MOTLEY

Flowerwood Nursery, Inc.
6470 Dauphin Island Parkway
Mobile, Alabama 36605

Flowerwood Nursery is using several different fungicides for different fungus problems. Our fungicide program begins before we take the cuttings. It is necessary to start off with clean, fungus-free stock plants. The cuttings' first fungicide treatment begins right after they have been cut. They are dipped for 15 to 20 minutes in captan 50 WP mixed at a rate of two pounds per 100 gallons of water, with no sticker. This is the manufacturer's recommended rate. The cuttings are still in the burlap sack where they were placed directly after cutting. After soaking they are spread out on tables under light mist until they are ready for planting.

Our second step of fungicide use is spraying right after the cuttings have been planted in the propagation beds. This is done every seven days as a general spraying. It is done in the afternoon 30 to 40 minutes after the mist clocks have been cut off. We wait this long to allow the cuttings to dry before spraying. We spray with a Bean 200-gallon, 8-hp sprayer mounted on a half-ton pickup truck frame. This makes it easy to drive down the center of the greenhouses.

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The fungicide we use is Benlate, prepared at a rate of 1 lb. per 100 gallons of water. With this spraying, we use a sticker, Nu-Film, at a rate of ½ cup per 100 gallons. Benlate is a systemic fungicide, which takes two to three hours to react. Benlate, as is the case with all fungicides, will not cure the problem but only control and prevent further fungi infection. We have found Benlate to be safe on almost all ornamentals at the rate of 1 lb. per 100 gallons. We do not spray Benlate on *Juniperus horizontalis* 'Bar Harbor' because of suspected toxicity. (This is only our opinion.) The next week we spray with captan 50 WP at the rate of 2 lbs. per 100 gallons of water, plus the ½ cup of Nu-Film. We alternate spraying because excessive use of any one fungicide may lead to buildup of resistant strains of fungi and loss of disease control. The reason we use only the two, Benlate and captan, on unrooted cuttings is that we have found them to be safe on a large number of ornamental crops.

Spraying is done with a hand-held boom, spraying over the top of the cuttings and letting the spray mist fall evenly over the cuttings. This technique keeps the pressure from blowing the unrooted cuttings to one side or out of the pots.

The next step in our fungicide program is routine spraying every 10 to 14 days. This is for rooted cuttings. We use the 200-gallon Bean or a 500-gallon Swanson blower sprayer. The Swanson blower sprayer is powered by a 132 hp tractor with an output of around 103 gallons per acre. We use a variety of fungicides for alternate sprayings every 14 days. Following is a list of these fungicides and the rate we use to mix them:

Daconil 2787 WP. We use this at the rate of 1½ pound per 100 gallons water. Fungi it helps prevent includes leaf spot, powdery mildew, phytophthora, and blight. We have found it safe on all rooted ornamental cuttings. We do not use it on unrooted cuttings.

Manzate 200 WP. Spray rate is 1 lb. per 100 gallons water plus one cup Nu-Film. Use this for highly effective contact control of stem and crown rots, alternaria blight, phytophthora leaf spot, and rhizoctonia blight.

Subdue. This is a systemic. Used as a drench at the rate of 2 oz. per 100 gallons of water for control of root disease. Also used as a spray on azaleas at the rate of 1¼ oz. per 100 gallons for control of pythium, phytophthora, and other water-mold diseases.

Ridomil. Also used as a drench at the rate of 4 oz. per 100 gallons water. This is the same as Subdue but may vary in price.

Triforine EC liquid. Rate of 12 oz. per 100 gallons water. We use Triforin mainly on *Photinia fraseri* for control of leaf spot, repeating every 14 days or as needed to maintain control. It is also good for powdery mildew with no mildew resistance.

Banrot. As a drench at the rate of 1 lb. per 100 gallons water. We use it to control damping-off root and stem rots and diseases caused by water-mold fungi.

Zyban. For a broad spectrum systemic and contact control of anthracnose, leaf spot, powdery mildew, and stem twig blight. Spray rate of 1½ pounds per 100 gallons water with ½ cup Nu-Film.

Kocide. For control of bacterial spot on *Euonymus japonicus*, var. *aureo-marginata* 'Aureomarginata'. Rate of 1½ lbs. per 100 gallons water plus ½ cup Nu-Film.

All of the fungicides and the rates as listed above have been working for us in our fungicide spray program. Most of these are available under other trade names. The important thing is the active ingredient, which is given in Table 1. We also use the "shotgun" approach. This means you see a problem, you identify it and then use the recommended fungicide for that particular fungus.

Spraying uniformly over the area with a boom-type sprayer insures good coverage and good control by your fungicide. On unrooted cuttings we spray over the bed almost to runoff, then mist.

Last but not least—safety first. Know your fungicide. Read the label, even the small print. Check your equipment for leaks, clogged lines, clogged nozzles, and clogged strainers. Calibrate your equipment frequently for proper output. Wear respirators and protective clothing.

Table 1. Active ingredients of fungicides used.

Common name		Active ingredient
Benlate	—	benomyl
Banrot	—	etridiazole + thiophanate methyl
Captan	—	captan
Daconil	—	chlorothalonil
Funginex	—	triforine
Kocide	—	copper hydroxide
Manzate	—	maneb
Ridomil	—	metalaxyl
Subdue	—	metalaxyl
Zyban	—	mancozeb + thiophanate methyl

HERBICIDES USED IN PROPAGATION AT WIGHT NURSERIES

MARTY LANGMAID

Wight Nurseries Inc.
P.O. Box 390
Cairo, Georgia 31728

Herbicides play an essential role in the propagation of woody ornamentals at our nursery. A large percentage of our propagation is done in outside areas where blow-in weed seed can be a problem. Our weed control program consists of selective use of post- and preemergence herbicides and minimal hand weeding.

The majority of our crops are propagated in either outside mist areas or greenhouses. The medium we use is pine bark: sand, 4:1(v/v). We do not use composted bark, it is green. In addition to these areas we produce one crop a year of bare root conifers in sandy ground beds at our River Division.

PREEMERGENCE HERBICIDES

In our outside areas our primary herbicide is Ronstar G (2% oxadiazon) for broadleaf propagation. We apply this before sticking cuttings at 200 pounds per acre actual material. It is applied with either hand-held spreaders or by plane in large areas. We repeat this application every 60 days.

Nandina domestica 'Nana Purpurea' is the only cultivar we avoid with this herbicide treatment. We get puckering of the foliage and slower growth when herbicides are used. Once rooted we switch to Scott's Ornamental Herbicide 2, (OH-2) (2% oxyfluorfen and 1% pendimethalin), applied at 100 lbs. per acre actual material. We have not yet proven the safety of using OH-2 in the rooting process but it does provide better weed control over Ronstar. Our major concern in our outside mist areas is with our second application. It is difficult to remove herbicide granules from the new growth to prevent burning. The small droplet size of the mist does not physically remove the granules as well as larger droplets from impact sprinklers. This is mainly a problem on *Photinia fraseri* and *Lagerstroemia* species, which have sensitive soft new growth. These plants are skipped over when this is a concern.

In conifer propagation we are using Scott's Ornamental Herbicide 2 applied before sticking at 100 lbs. per acre, actual material. It is reapplied at a 90-day intervals during winter and 60 day intervals during the remaining season. Experiments on the nursery have shown OH-2 to be safe and effective on conifers during rooting.

Conifers propagated in our ground beds are also treated with OH-2 before sticking. The only difference here is that the sandy soil is treated with methyl bromide gas at 400 lbs. per acre by a private contractor. Even with the gas treatment a pre-emergence is necessary for control of blown-in weed seeds.

Our greenhouse propagation is done primarily on the ground, which is covered with rock or asphalt. No pre-emergence herbicides are used when houses are covered due to plant damage that can result from volatilization of herbicides. Covers are removed in spring after danger of frost is gone. Our propagation of broadleaved plants begins in May. Before flats are put down rock is treated with Ronstar G at 200 pounds per acre actual material. Flats filled with medium are put down and also treated with the same rate of Ronstar G before sticking. This is the only pre-emergence herbicide application made in our greenhouses. Here again *Nandina* species are not treated to avoid problems. Seedlings are not treated with any herbicides. Many liners are planted out that season; carry overs are hand-weeded as needed. Because of the limitations in covered houses more hand weeding is done here than in any other area.

The deep well used in propagation is not chlorinated so walkways of either rock or asphalt get an accumulation of algae over time. We use copper sulfate broadcast by hand to prevent slips and falls.

POST-EMERGENCE HERBICIDES

Our primary post-emergence herbicides are Roundup (glyphosate), or Diquat (dibromide monohydrate). Roundup or Diquat is used at 2 quarts per 50 gallons water. Roundup is sprayed twice a year around perimeters to keep blow-ins to a minimum. We also spot spray with either of these products in all areas including greenhouses. Since diquat is an aquatic herbicide, it is used in heavy water-use areas such as propagation where there would not be enough absorption time for Roundup to be effective. Diquat is a contact herbicide and has replaced Paraquat, or Gramoxone, (paraquat dichloride) on our nursery because of its lower toxicity to employees.

Prevention is the key to our weed control program. Weeds, once they get started, propagate themselves much more readily than we can produce plants. One weed is too many. Through the selective use of pre- and post-emergence herbicides on a regularly scheduled basis, we can eliminate most weeds and safely propagate most woody ornamentals. Hand weeding will never be outdated but minimized to escape weeds. Herbicide screening trials are conducted each year as new products become available. In this business it pays to stay ahead of the weeds.

INSECT AND MITE CONTROL USED IN PROPAGATION

PATRICIA P. COBB[1]

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Control of insect and mite pests remains an important part of the total scheme of propagating plant materials. Ideally, control of these pests is only a small part of the total management program. Both cultural and chemical practices are important in keeping insect and mite pests under control. The following includes general suggestions for cultural control of pests and comments about chemical control of spider mites, whiteflies, and thrips—three important pests in plant propagation situations.

CULTURAL CONTROL

Cultural control of pests in plant propagation operations is as important as chemical control in most cases. The following are a few important points to remember:

a) **Pest-free stock plants:** Many insect and mite problems on cuttings can be traced back to the presence of these pests on stock plants. Care should be taken to examine stock plants regularly and control pests there before cuttings are taken. Low levels of mites and insects on stock plants can be controlled more effectively than high levels of these pests. If possible, keep cuttings in areas apart from stock plants. If stock plants are too badly infested for control to be achieved, destroy them and start over. Cuttings received from other growers should be examined as closely as possible.

b) **Sanitation:** Sometimes abandoned plant stock or weakened cuttings are left in close proximity to maintained propagated plant material. Insect and mite infestations may go unobserved in areas where plants are discarded. Regular removal of discarded or unmanaged stock can reduce pest populations in the area. Dumping sites should not be close to maintained areas.

c) **Weed control:** Mites and some insect pests may be attracted to certain weeds and move from weeds into propagated material. Weeds should be eliminated or mowed regularly in areas adjacent to propagation sites. Weeds within propagation areas should also be eliminated.

CHEMICAL CONTROL

Chemical control used in plant propagation includes control of pests on stock plants and on cuttings. Some pesticides are registered for use only on woody plants, others only on foliage plants; some for only greenhouse use, others for a variety of sites. Some are

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registered in some states and not in others. Always read the label for use information and restrictions, and follow label directions. All pesticides listed here are recommended at label rates. Remember that *good coverage* (contact between pest and pesticide) and *proper timing* are essential in controlling pests. This may mean *staying on schedule* with treatments. *Alternating pesticides is important in* delaying or preventing pest resistence.

Spidermites (two-spotted) damage plants by extracting plant juices. Their presence may go unnoticed when levels are low. Some common miticides are as follows: avermectin (Avid®), fluvalinate (Mavrik®), dienochlor (Pentac®), bifenthrin (Talstar®), aldicarb (Temik®), hexakis (Vendex®), tetradifon (Tedion®), as well as smoke generators containing dichlorvos and sulfotep.

Whiteflies are closely related to scale insects. Immature stages extract plant juices and produce honeydew. Whiteflies should be controlled while numbers are low. Severe populations are difficult or impossible to control. The sweet potato whitefly is now a pest on ornamentals in the southeastern U.S., and is especially difficult to control. Controls are directed toward both adult and immature whiteflies. Some insecticides that have indicated effective whitefly control by growers and/or researchers are as follows:

a) for adult whiteflies: sulfotep (Dithio®, Plantfume®); pyrethrins plus pipernyl butoxide (Pyrenone®); resmethrin.
b) for immature whiteflies: aldicarb (Temik®); oxamyl (Vydate®).
c) for both adult and immature whiteflies: bifenthrin (Talstar®); bifenthrin (Talstar®) plus acephate (Orthene®); endosulfan (Thiodan®); permethrin (Pramex®); fluvalinate (Mavrik®); acephate (Orthene®).

Thrips are small insects that damage a wide variety of wild and cultivated plants by rasping plant tissue. Their feeding distorts new plant growth and damages buds. In dry springs or autumns they may move in great numbers into plant propagation areas, including greenhouses. Insecticides may give limited control of thrips certain times of the year. Some insecticides used for thrips control are acephate (Orthene®); fluvalinate (Mavrik®); permethrin (Pramex®); bifenthrin (Talstar®).

In summary, insect and mite control for plant propagation includes cultural and chemical procedures. There is no substitute for regular inspection of plant materials in order to detect and control pests while they are at controllable levels.

FUMIGATION—BASAMID

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16127 Winans Avenue
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In an effort to reduce production costs and to ease weeding hours in seed beds, our nursery initiated tests in 1985 using a chemical soil sterilant, (active ingredient: dazomet). A rather intensive review of all the IPPS Proceedings does not show reference to this product.

Over the years our nursery has used methyl bromide as the fumigant for seedbed areas, with varying degrees of weed control. We had this product applied by private applicators, and the price per acre has steadily increased for the past six years. Our quotation for spring, 1987 was $1,100 per acre! In addition to the product cost there still remained a labor cost incurred in the removal and disposal of the polythene sheeting. This is very distasteful and time-consuming. Weed control has been less than perfect. Weeds started appearing in late June on October-treated areas.

Margaret Scott, IPPS G.B.&I. Region, and Wayne Lovelace, Eastern Region, shared information on an Orbit-Air Gandy Spreader to apply Basamid. Based on their information and our own evaluation, we have made Basamid-Granular the soil fumigant in our standard production practice. This is a product from BASF. When incorporated into the soil, it has nematicidal, fungicidal, and herbicidal effects. Therefore, it is classed as a chemical soil sterilant.

The product is a white micro-granular formulation. The granular form is easy to apply with the Orbit-Air Gandy Spreader. We use it at our nursery in the seedbed and in greenhouse fumigation. According to the literature, Basamid-Granular has been used around the world in ornamentals, vegetables, tobacco, orchards, vineyards, and hopfields. Residue analyses carried out on a wide range of vegetables showed no dazomet residue. The product has moderate oral toxicity, with LD50 value of 640 mg/kg.

Basamid-Granular was first tested at John Zelenka Evergreen Nursery October 2, 1985; 0.4 acre next to the test plot was treated with methyl bromide. The soil temperature was 54°F.

The June 21, 1986 evaluation showed weed seed germination in the methyl bromide plot but absolutely no weed germination in the Basamid treatment. In both areas, as one would suspect, woody plant seed germination was not inhibited. Additional treatments were conducted on November 6, 1986, (45°F soil temperature) May 5, 1987, (54°F soil temperature) and on September 29, 1987, (50°F soil temperature). Some important points that we have learned from the label and from experience at our nursery are summarized below:

PRIOR TO TREATMENT

Soil temperature. Minimum of 45°F (7.5°C), maximum of (20°C). The label reads 10°C. This temperature range is very important.

Soil preparation. Work soil to a seedbed condition, with all soil clods pulverized completely.

Soil moisture. Soil should be at 60 to 70% of its water-holding capacity for seven days (label reads 5 to 14 days).

Prevention of damage. Before greenhouse treatment all crops must be removed and all doors closed and locked. If a portion of a greenhouse range is to be treated, poly curtains must be firmly in place. In the field do not allow Basamid-Granular to come within 18 in. of plant roots.

TREATMENT

Depth of treatment. We rototill to a depth of 8 to 12 in. prior to application.

Application. We use an Orbit-Air Gandy Spreader, (Model 6224), which gives us excellent even distribution. Our product rate per acre is 300 lbs. The label rate is 20 to 40 g/m for herbicidal control. Current price is $3 per pound, equating to $900 per acre.

Incorporation. This is done immediately after application. We use a Howard rotovator, going no deeper than the depth of soil preparation.

Sealing surface. After incorporation, we irrigate with ¼ in. of water daily for seven days. Label advises to compress soil by rolling and then watering. We do not do this. Label also suggests to cover soil with polythene sheeting after watering. We do not do this.

AFTER TREATMENT

Aeration. Seven to 10 days after application, temperatures are about 50°F, (10°C), and we loosen the soil by rototilling. Depth should not exceed the original tilling. In another 10 days we till again and prepare our seed beds.

Germination test. After aeration soil samples are taken at various areas in the treated plot. We sow either lettuce or rye seed into this soil and observe germination. The label suggests sowing cress seed (*Lepidium sativum*).

Planting/seeding. If lettuce/rye seed germination is satisfactory, we then prepare the area with a bedformer, and we are ready to seed, plant liners, or move plants back into greenhouse beds.

Our seed germination was excellent following treatment and weed control was far superior to previous years of methyl bromide application. Product cost saving was $200 to $300 per acre, plus a sizeable labor cost saving since we did not have to dispose of the poly tarp. I also have data on the hand weeding dollar savings in the Basamid versus methyl bromide plots in 1986. Once again, we have a product from agriculture that is applicable to the nursery community.

If anyone is interested in testing Basamid-Granular and applying with an Orbit-Air Gandy Spreader, please contact me for spreader setting, tractor speed, and other data that will save you time in calibration.

MECHANIZATION OF LOADING PLANT MATERIAL: MOBILE LOADING DOCK AND TELESCOPING CONVEYER

GREGORY JOHN LANGELER

Chesapeake Nurseries Inc.
Pemberton Drive
Salisbury, Maryland 21801

Loading trucks from stationary docks using conveyers has been standard procedure for a long time. Both cost a great deal of money and are permanent fixtures of a loading operation. As our research into the applications of this technique at Chesapeake Nurseries began, we saw many problems with it.

The nursery was rapidly expanding and the demands of our loading system were changing. After many discussions, the idea of a mobile loading dock on a truck that could be moved from trailer to trailer as loading required was considered. A 50-ft. conveyer was considered necessary to load 40-to-45-ft. trailers used in shipping efficiently. We felt a moveable dock 50-ft. long would be at best very awkward and inefficient, but a 25-ft. truck would be very easy to move. We began to look into a way to build a 50-ft. conveyer that would slide together into 25 feet.

Our conveyer consists of three main components. The first is two conveyer sections, the top one 25 feet in length and the second 28 feet in length. The second component is the transition plate that allows plants to slide from the top belt to the bottom belt. The third key part is the dock itself. (See Figure 1).

The two conveyers were hand-built, and the bottom conveyer rolls under the top belt on 6 in. v-groove wheels. The conveyer is fully operational at any length from 28 ft. (fully closed) to 50 ft. (fully extended). Both conveyers are 18 in. wide and can carry up to 75 lbs. per square foot.

The transition plate is made of a high-density polymer with a low friction coefficient. As the plants come off the top belt, their sizeable labor cost saving since we did not have to dispose of the poly tarp. I also have data on the hand weeding dollar savings in the Basamid versus methyl bromide plots in 1986. Once again, we have a product from agriculture that is applicable to the nursery community.

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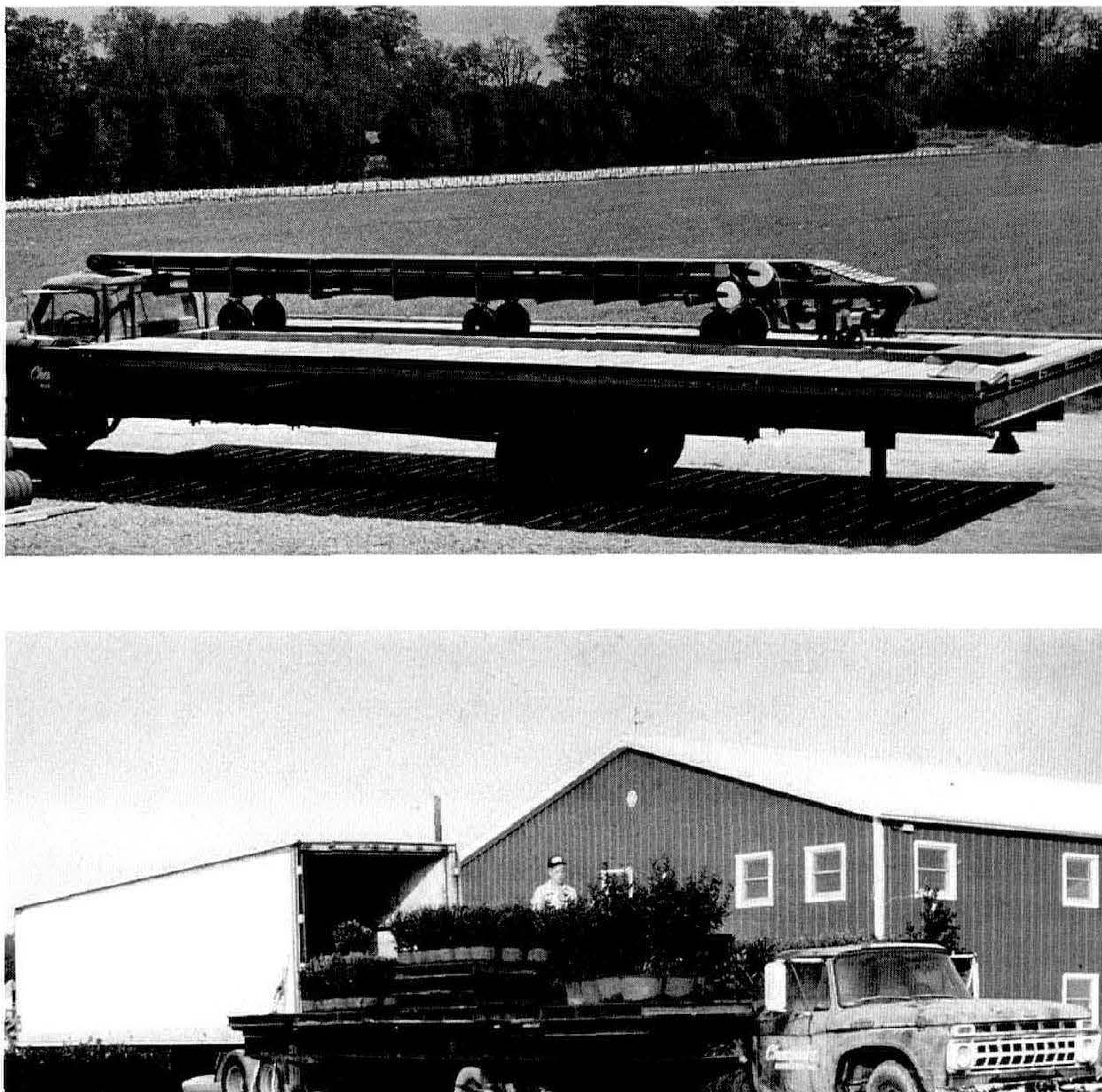

Figure 1. *Above.* Mobile loading dock and telescoping conveyer. *Center.* Loading dock with plant material. *Below.* Conveyer in use.

momentum carries them down the transition plate to the second belt.

In the nursery trade almost all equipment must be modified to fit each nursery's particular application. We feel this is also true of our conveyer system. This system offers a low-cost, highly efficient means to load plant material that can be modified as needed.

BEDDING PLANT PRODUCTION IN A "STATE-OF-THE-ART" ENVIRONMENT

BILLY POWELL[1]

Powell Plant Farms
Route 3, Box 1060
Troup, Texas 75789

Because of its seasonal nature the bedding plant industry is a difficult candidate for automation. However, changing markets, labor, and the rising costs of production materials have many growers considering automation technology.

Powell farms of Troup, Texas, a bedding plant grower since 1958, started considering a high-tech facility in 1982. Their existing facility was too extensive and productive to replace, so the facility of range was designed to integrate with it.

In the process of design to accommodate the two type production systems, Powells avoided one of the major pitfalls facing growers switching to high-tech automation—automation bottlenecks.

An example of a common bottleneck is having one rolling table unloader with a capacity of 1000 flats per hour as the sole source of a supply for a conveyer truck-loading system with capacity of 3000 flats per hour, which would be needed during peak season. Unless the capacity of this table unloading system is increased, either by supplemental hand work or by mechanical means, there is a bottleneck. Powells' solution to this problem is leaving enough room around each system to accommodate the hand labor required during peak season. By doing this, each mechanical system can be operated at its peak of efficiency, year-round and overloads are quickly handled by temporary help.

One area in which this solution did not work was seeding. All seeds are germinated in plug flats, making hand seeding impossible. Also, accuracy required in seed placement coupled with the volume necessary to meet company needs ruled out temporary or

[1] Paper presented by Bill Corbin

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makeshift equipment. Powells chose a drum seeder built in Florida by S-K Designs.

This drum seeder meets volume requirements during peak season and accurately places the seed in the planting cell. Rows of seed ports across the face of the drum retrieve seed from the seed hopper by vacuum. As each row rotates through the hopper, one seed is pulled up over each port. The drum rotates in sync with the oncoming plug flat. This flat is held in a precise position on the flat conveyer by cleats. Just before the flat reaches the drum, the planting cells are lightly packed and indented by a rolling dibbler. As the seed ports on the drum align with rows of planting cells in the flat, the seed is placed by a quick jet of water from the seed port. At the Powell installation, flats then pass under a solid materials dispenser. This, in turn, is followed by a low-pressure water bath. Water is applied from a height of 4 in. in 1/8 in. streams with a maximum water pressure of two psi.

Four different sized plug flats are used. They are a 512, 392, 200 and a 72. Eleven drums are used, each having different spacing, seed ports per cell, and port size.

Seeded plug flats then move into the plug house complex via a power roller transport line.

This Exolite-covered complex is 85,000 square feet in size and divided into six compartments. The flats are stored on 36-flat rolling tables, which rest on rails 23½ in. above the floor.

Heating in the complex is by hot water traveling through pipes 20 in. below rolling tray bottoms and along the house perimeter. Cooling is by pad and fan, ridge row vents and shading. A unique feature of this complex is the central air intake corridor. The sides of this corridor are the cooling pads for the complex. Air is drawn into this corridor through overhead louvers. Turbulence created in the air improves air flow through the pads and reduces energy costs by about seven to nine percent. Fans, located on exterior walls, draw air across the distance of the house, which is about 100 feet.

Each compartment is equipped with a MEE fogging system. All compartments are equipped with automatic overhead shading. This shading is a function of foot-candle output of the sun at table-top height. The shading material is a 70% shade cloth and has a foil topside for radiant heat reflection.

Each bay or house structure has an overhead traveling boom. These booms are connected to the fresh-water system as well as to an injection system. Booms can be set to water the entire bay or any portion of it.

Plugs leave the plug house complex via power roller transport going to the transplant area. Each flat is removed from the rolling tables and punched from the bottom before going to the transplant line. This loosens the plugs in the cells for easy removal.

Transplanting is hand done on three transplant lines by 18 men, six per line. Each person transplants 72 plants per minute. This gives the overall transplanting operation a maximum volume of approximately 1000 flats per hour.

Flats with liners filled and dibbled come to the transplant area from the soil mixing room. The soil medium is custom mixed here on the farm. Equipment required for this operation consists of one main conveyer, which passes under several hoppers. Each of these hopper's output onto the conveyer is regulated by computer. Medium is mixed by a horizontal batching mixer having a two cubic yard capacity. Medium is then stored above the conveyer going to the dibbler. Elements used in the soil medium are peat moss, sand, foam, vermiculite, lime, Osomocote, and trace elements. Plug flats are washed and reused after transplanting. They can be recycled approximately three times.

Transplanted flats travel by conveyer to accumulators where they are loaded onto 48-flat rolling tables. These tables then travel under a low pressure, high volume water and fungicide application administered from a height of about 6 in. Tables then await transportation to the grow-out areas in the headhouse.

The headhouse is glass-covered and almost 1000 feet long. It has ridge-row vents for cooling and is equipped to hang 8000 baskets. Embedded in its floors are guide rails for the trains. These trains transport 48-flat rolling tables to and from the grow-out areas, to the load-out facility, then return the empty tables to storage rails in the transplant area.

The grow-out houses are glass covered. They have overhead heat, perimeter heat, and heated floors. Watering is by overhead automatic sprinklers. This sprinkler system is connected into an injection system allowing fertilization and other types of chemical applications. In addition, the houses are equipped with ridge row-vents, pad and fan cooling and automatic overhead shading. Each house of the four-house complex covers 1¼ acres. Each has its own roll-out area. Moving here is done manually. To start the operation, one must place the bridge rails between the house rails and the outside roll-out area rails, then windows in the end of the houses must be raised. Eight men can roll out or back the entire 5 acres in about one hour.

The outside roll-out area is equipped with automatic overhead sprinklers. The sprinkler heads are a combination of spinners and pulsating types. One area of 1¼ acres is equipped with automatic overhead shading. This area is located on the south side of the grow-out houses and is well protected from the wind. The entire five-acre roll-out area is served by trains and is floored with concrete. Drainage is by 12-in. open paths in the cement floors.

Crops move via trains from the grow-out areas to the load-out area. Flats are loaded onto 88 10-in. conveyer belts according to cultivar. These conveyers move in either direction to facilitate loading and unloading. Each will hold 96 flats.

These conveyers are housed in a 25,000 square foot glass-covered house. Above these loading conveyers are automatic carousel basket facilities with a total capacity of 15,000. Glass covering gives this facility a dual purpose. During peak season it is used as a load-out facility; off season it is used as a grow-out area.

The 88 ten-inch conveyers move flats up automatically on demand. Across the unloading end of the conveyers are three conveyer belts each going to a different truck that is being loaded. Load-out crews remove the required number of flats to fill the order and place them on one of the three belts going to the trucks. These three conveyers pass under a water-down facility, then transfer flats to a boom-type unit. This unit will extend into the hallway of shelved trucks enabling it to carry the flats to the front of that truck. Flats are then hand placed on the shelves. Approximately 20,000 flats can be moved through this system in one day.

Automation will save labor, increase plant quality and, if correctly designed, increase volume. However, a system must allow for seasonal fluctuations to remain an economical unit for operation.

USES FOR COMPUTERS IN PLANT PROPAGATION[1]

DEWAYNE L. INGRAM AND THOMAS H. YEAGER

Ornamental Horticulture Department
Institute of Food and Agricultural Science
University of Florida, Gainesville, Florida 32611

Computers can be an effective tool in management of information and control of "real-time" events or processes. Common limiting factors to expansion of a plant propagation business are ready access to known propagation techniques for less common or difficult-to-propagate plants and the management and analysis of information gained through experience with particular plants. The optimum flexibility and management of environmental control devices may also limit the maintenance of an environment suitable for sensitive plant materials. Recent advancements in microcomputers can help in this area.

Computer programs have been written to assist in the calculation of rooting hormone formulations, calculation of dilution ratios for fertilizer injection into an irrigation system, and for storage and retrieval of propagation techniques for selected landscape plants.

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Landscape Plant Propagation Information (LPPI) is an interactive computer application developed for retrieval of propagation information on several hundred landscape plants. LPPI has been written in S1032, a database manager that can be accessed through the Institute of Food and Agricultural Science (IFAS) Computer Network, available through Florida County Extension Offices. The user can list plants in the database and retrieve information on individual plants by entering all or part of the scientific or common name.

ROOTHORM is an interactive computer program that will run on IBM-PC compatible microcomputers. The user inputs a specific hormone, desired hormone concentration, and final volume. The program then calculates the ingredients needed and recommends procedures for liquid or talc formulation preparation. Specific concentrations of rooting hormones are required for optimum rooting of many difficult-to-root plants, and formulating these concentrations involves cumbersome calculations and conversions. This program eliminates the mathematical errors commonly made when calculating the volume and/or weight of ingredients in a rooting hormone formulation.

SOLUFERT and FERTDRY are also interactive programs designed to run on IBM-PC compatible machines. They both calculate the dilution ratios necessary to obtain the desired concentrations of nitrogen, phosphorus, and potassium in the irrigation water. FERTDRY is to be used when dissolving dry fertilizers for injection and SOLUFERT is used when fertilizers are purchased as solutions. These are production aids that allow the nursery operator to make error-free calculations that are performed routinely.

LANDSCAPE PLANT PROPAGATION INFORMATION RETRIEVAL SYSTEM

Propagation information has been collected from scientific publications, plant propagation publications, and communications with experienced nursery operators. The database contains general descriptive information on each plant, the primary and secondary means of propagating the plant and important techniques to consider in each suggested propagation method. Possible propagation methods include cuttings, seed, layering, grafting and budding, and division. The information on each plant may be incomplete but reflects information collected to date. The database will be continually updated as additional information is obtained. Allowing each user to access the latest version of the database is the primary advantage of a database within a computer network. The restricted access imposed by such a system is a disadvantage. However, when the database becomes more complete, the information may be distributed by other methods.

LPPI can be accessed from the Ornamental Horticulture Sub-menu of the IFAS-VAX MENU. The program has been written to take advantage of the features of a DEC VT-100 terminal. If accessed by another terminal it should run but the presentation may be incorrectly formatted. A brief abstract is presented each time a user calls the program and the program is menu-driven.

The user may retrieve information by specifying the scientific or common name of a specific plant if the correct spelling is known. Otherwise, the user may elect to search for a plant in the database by entering a portion of the scientific or common name. A list of plant names with the sequence of letters entered will be displayed and the user may then enter the complete scientific name of the desired plant to obtain available propagation information.

CALCULATING ROOTING HORMONE FORMULATIONS WITH A MICROCOMPUTER

Although rooting hormones of various concentrations can be purchased, it is often desirable to formulate liquid or talc materials of concentrations different from those commercially available. Preparing-your-own may also be more economical if the nursery consumes large quantities of rooting hormones. This program allows the inclusion of IBA, the potassium salt of IBA, NAA, and the sodium salt of NAA. The program takes into consideration that IBA and NAA are relatively insoluble in water and must be dissolved in alcohol before adding water. ROOTHORM formulates concentrations of IBA and NAA of 8000 ppm or less in 25% alcohol and concentrations greater than 8000 ppm in 50% alcohol. These alcohol contents will allow the hormones to stay in solution at room temperature.

The salts of IBA and NAA are soluble in water and little or no alcohol is required. The salts are more expensive than pure compounds and contain less active ingredient on a weight basis. The potassium salt of IBA is only 75% as active as the pure compound and the sodium salt of NAA is 90% as effective as pure NAA. These facts are considered in the options and calculations provided in ROOTHORM.

Each time the user runs ROOTHORM the option of reading the abstract and general instructions is provided. The user must then choose to calculate a liquid or talc formulation and the specific hormone or combination of hormones and the desired concentration(s) to be included. The type of measuring equipment available differs widely from nursery to nursery. Therefore, the user may choose the units of measure for the weight of hormone to be included and the final weight or volume of the formulation. After the final volume or weight is entered into the program, the amounts of individual components are calculated and presented on the screen or they can be printed. A step-by-step preparation procedure is also given.

DILUTION CALCULATIONS FOR INJECTING FERTILIZERS THROUGH IRRIGATION

The user must know the analysis or grade of fertilizer or fertilizer component to be injected (example 16-4-8); the desired parts per million (ppm) of nitrogen, phosphorus or potassium, the amount of these elements occurring naturally in the irrigation water, the dilution ratio(s) of the injector and the total volume of the mixing tank. In addition, the weight/volume ratio of the solution fertilizer is required for the SOLUFERT program. This is simply the pounds of fertilizer per gallon of solution that can be obtained from the manufacturer.

FERTDRY allows the user to make calculation for injection of blended dry fertilizers such as Peters' or Miller's 20-20-20 or calculations may be made for dissolving individual fertilizer compounds such as ammonium nitrate and calcium nitrate for injection into irrigation water. A list of fertilizer compounds suitable for injection is provided in the program. The user simply chooses from this menu and enters the appropriate information as outlined above when prompted by the computer program.

In SOLUFERT, if the dilution ratio of the injector does not allow for the direct injection of the fertilizer solution into the irrigation system, the program will indicate how to dilute the concentrated fertilizer before injection. Step-by-step procedures are given to help the nursery operator implement the output from these calculations.

COMPUTER SOFTWARE AVAILABILITY

ROOTHORM, SOLUFERT AND FERTDRY can be purchased from the Editorial Department, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611. The current price for each software program and documentation is $20. There are other software packages that have been produced by the University of Florida that might be of interest to nursery operators. A complete listing of those can be obtained by contacting the Editorial Department at the same address.

USE OF INFRARED HEAT IN A PROPAGATION ENVIRONMENT

SAM ALLEN

International Forest Seed Co.
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International Forest Seed Co. (IFSCO) has an active program breeding loblolly pine for fusiform rust resistance. Controlled crosses of resistant parents were made in 1983–1985. Seedlings derived from these crosses have been established in cutting orchards.

During the winter of 1986–1987, a 108 ft. × 41 ft. propagation greenhouse was constructed at IFSCO's nursery near Odenville, Alabama, to root cuttings from the rust-resistant selections. Loblolly pine is a difficult species to root. The best rooting reported in the literature is 68% (2).

Greenwood *et al.* (1) reported that the distribution of mist accounted for 75% of the variation observed in rooting loblolly cuttings. For this reason we decided to use a fog system for propagation. The use of fog for propagation has been addressed several times in this and other publications so will be treated briefly here. We have been satisfied with a Mee system in operation for several years and decided to use the Mee II Cloud Fog System in the new facility.

Fog lines were placed 10 feet apart as were nozzles on each line. The system was also designed to aid in cooling. Nozzles were placed 18 feet apart along the air intake vent as suggested by the manufacturer. Fans were installed to exhaust 1½ volumes of greenhouse air per minute. As a general rule of thumb, greenhouses that utilize wet pads for cooling require one air exchange per minute. The manufacturer recommends one air exchange per two minutes.

This combination of fog volume and airflow was not adequate during the summer of 1987. Temperatures would exceed 100°F and foliage would dry during the heat of the day. Additional nozzles were installed and a travelling boom irrigator was run across the cuttings to keep the foliage wet.

The production system at IFSCO utilizes 40-cavity multipots, which are placed on growing frames. These frames, which hold 2,400 cavities, are then transported with a tractor and front-end loader. An under-gravel hot water heating system had not held up to the weight of the tractor, therefore, forced air and infrared heating options were assessed.

The primary advantage of infrared heat is lower energy consumption. An infrared system used 62% less fuel than gas-fired unit heaters with polyethylene convection tubes (3). Purported disadvantages of infrared heat such as dense plant canopy causing cool soil temperatures and non-uniformity of heat distribution, we felt, would be reduced in a fogged environment.

A four burner-one exhauster Reflect-O-Ray infrared system manufactured by Combustion Research Corp. was installed. The system became operational in February, 1987. As of this writing, the heating system has only been in use for three months so adjustments are still being made.

On December 17, 1987, air and growing-medium temperatures were taken using a Standard Oil Engineering Plant Stress Monitor to evaluate heat distribution characteristics throughout the greenhouse. Medium temperatures taken across the width of the greenhouse revealed an average temperature differential of 5.5°F between warmest and coolest areas. Warmest areas were under the heat lines, coolest areas were near the outside walls and in the middle.

Growing medium temperatures averaged 3.8°F warmer than air temperatures just above plant height. This is because infrared systems heat solid objects, which then heat the air. Traditional forced-air systems heat the air which, in turn, heats solid objects. The comparatively warm medium temperature is advantageous to rooting, but the non-uniform heat distribution causes variable rooting responses.

Our system requires an 8-minute minimum burning period to purge acid, which can build up in the lines. This causes cycling of our temperature control system. During low heat requirement situations, 8 minutes of heating will trigger a cooling phase. This not only wastes heat but contributes to uneven temperature distribution.

Infrared heating systems have potential in a propagation environment but, however, are more appropriate in a northern climate where fuel savings could be better realized.

Acknowledgements. Thanks are given to Dr. Steven E. Newman, Assistant Professor, Mississippi Agricultural and Forestry Experiment Station, for assistance with infrared thermometry and data collection.

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SOUTHERN REGION QUESTION BOX

The 1987 Southern Region Question Box was moderated by *Carl Whitcomb and Bryson James.*

QUESTION FOR CARL WHITCOMB: How are plants in the Gro-bags fertilized?

CARL WHITCOMB: The key is the development of roots *through* the fabric. The way it works is different from above ground. We want to encourage the nurse roots so fertilizer should be spread both inside and outside the bag. If liquid is used through the drip system be sure a sizeable area is wetted and fertilized outside the fabric.

RALPH SHUGERT: Is drip irrigation important with Gro-bags?

CARL WHITCOMB: Not really. Usually natural rainfall is enough to carry the fertilizer into the feeder roots. The quality of the liner affects results in the same way that putting more money in the bank affects the balance. It has the advantage of getting more interest as well as being bigger in the first place. There is a multiplication factor involved.

BRYSON JAMES: Why are you fertilizing the 10 percent of the root system that is outside the bag if you are harvesting the 90 percent that is inside the bag?

CARL WHITCOMB: Since absorption is occurring primarily at the root tips, it is important that the fertilizer be placed in this area. It appears that the material is translocated and utilized inside the bag.

BRYSON JAMES: What about the tips *inside* the bag?

CARL WHITCOMB: The utilization outside is due to growth requirements but inside is due to the production of carbohydrate, which is an important requirement for successful transplanting.

TED BECKETT: Have we harvested enough of these plants to be sure what is really happening?

RALPH SHUGERT: What exactly is the "escape root"?

CARL WHITCOMB: The "escape root" is the one that actually goes through the bottom which is currently polyethylene. If it escapes, there is no constriction and, therefore, no benefit of the system on that root.

BRUCE BRIGGS: Will the constriction by the fabric cause the development of more branches?

CARL WHITCOMB: Yes. It will branch instead of circle.

TOM MERRIT: When we dig the plants, we break the plastic bottom and lose our sandy soil.

CARL WHITCOMB: Yes, that happens but mostly when the plants are dug early and roots have not yet branched enough to hold the soil mass together.

QUESTION FOR CARL WHITCOMB: When should these plants be harvested?

CARL WHITCOMB: They can be transplanted at any time. However, if the plants are making a flush of growth, it is best to wait until that growth hardens. A good clue is the size of the last-formed leaf. If it is full-size, the growth is usually hardened enough. Terminal and axillary buds should be developed.

BUDDY COLVERT: How do the Gro-bags perform as above-ground containers? Will the roots stop at the plastic?

CARL WHITCOMB: The roots will stop. Our problem above ground under Oklahoma conditions has been keeping the soil wet. We finally pushed the plants together, but then the roots grow from bag to bag and are a mess to separate.

QUESTION TO RUTH HENDERSON: What is the nozzle used on the sprayer that was moving across the tops of the plants like a small airplane?

RUTH HENDERSON: Precise information on this can be obtained from Keith Humphries, Ruakura Research Station. Hamilton, New Zealand.

CHARLIE PARKERSON: Could that type of applicator be used to spray plants in a room approximately the size of this meeting room by putting several on a boom?

RUTH HENDERSON: I have not seen it used that way, but it probably could.

RALPH SHUGERT: Is anyone using something better than Rout herbicide? We find this is one of our major costs.

BRYSON JAMES: Goal is a possibility. It is very inexpensive.

RALPH SHUGERT: We suspect that Goal is giving us poor color on some of our deciduous plants.

BRYSON JAMES: You must be very, very particular about timing and about using Goal inside the greenhouse.

BRUCE BRIGGS: We use our chemicals for tools but do not use them on all of our crops. We, too, have found liquid Goal to be tricky. You may not get rid of it for a year. However, our problems and climate in the Pacific Northwest are different from yours.

BRYSON JAMES: The only time it would be safe for deciduous plants would be when they were completely dormant.

BILL DAUGHTRY: We are using Goal during the dormant season at the rate of ½ pound per acre. This gives us three months control. We do not use it on liriope.

JOHN MACHEN: How far south can we grow Japanese maple? I saw it at Pleasant View Nursery near here and wondered.

CHARLES COX: It is not good south of Orlando and is better north of Tallahassee. It can be grown green as an understory tree in the southern extreme of its range. The trident maple is not too bad.

QUESTION TO BRUCE MOZELL: What is the bottom line cost on a good environmental sensor?

BRUCE MOZELL: A complex eight-station unit costs about $775. We know the electric plate units last about six months. Light sensors need to be dry and also need to be replaced frequently. The point, of course, is to have the sensors in the stressed areas of your setup, which means they wear out faster.

QUESTION TO ROY DAVIS: How do you prevent decay of pittosporum cuttings?

ROY DAVIS: We have changed from peat to a bark medium. They are a problem.

RALPH SHUGERT: Have you tried straight perlite?

ROY DAVIS: No, since we cannot convert the entire house.

CARL WHITCOMB: Don't forget the effect of the deep container. A deep container will improve drainage.

ROY DAVIS: We have also found that the Dramm nozzles at three-second intervals, 60 psi, do much better than other nozzles we have tried.

RUTH HENDERSON: We allow the cuttings to suberize over night, then stick them in sand.

SHIVU PATEL: Right now (October) is the best time to stick the cuttings.

QUESTION TO MICHAEL DIRR: How much carbohydrate is produced during rooting?

MICHAEL DIRR: Photosynthesis is down almost to the compensation point, and it doesn't pick up until rooting occurs. Until then you probably don't need more than 250 footcandles of light.

QUESTION TO MICHAEL DIRR: You referred to a rooting compound called PITP. Could you give us more information on the material?

MICHAEL DIRR: It came from the South Dakota School of Mines; it seems as effective as IBA. We have been trying it, and it looks good.

VOICE: What about rooting Japanese maple hardwood cuttings?

BRUCE BRIGGS: It is difficult. There are reports in the Proceedings.

RALPH SHUGERT: We have been able to get 60 to 65% rooting using bottom heat. Margaret Scott at the Efford Station, UK, gets about 62%.

MICHAEL DIRR: We use stocky cuttings and high hormone levels. K-IBA is easy to dissolve, but its penetration is not as good as a material in an organic solvent. Mike Bracken adds DMSO to K-IBA.

CHARLIE PARKERSON: We felt we needed to soak the cuttings longer and have used both K-IBA and K-IAA. We have also found Senegol, out of Efford Station, is good. It seems to give good intercellular movement.

I have another question. How far south can we grow *Erica* and *Calluna*?

MICHAEL DIRR: About zone five is best.

MIKE BRACKEN: We feel we get better caliper from tissue-cultured red maple.

BRUCE BRIGGS: If we try to put out small tissue-cultured plants, they don't take the stress.

MICHAEL DIRR: We found that tissue-cultured crabapple gave varied response in the field. It is probably best to grow them out a year, then cut them back. By then you really aren't gaining much from the tissue culture.

WAYNE SAWYER: There was a question on the use of B-9 on azaleas to induce cold hardiness. We are trying this and will be able to tell more next year.

GREG LANGELER: We use B-9 in late August on azaleas. It causes thickening of the tissue and seems to prevent the plants from breaking dormancy.

MICHAEL DIRR: There has been a question on sycamore cultivars, especially those resistent to anthracnose. 'Bloodgood' is probably the best.

RALPH SHUGERT: 'Bloodgood' is mixed up in the trade, and as a result not all Bloodgoods, so-called, are anthracnose-resistant.

DAVID MORGAN: A bacterium that also causes Pierce's disease in grapes is worse than anthracnose. It is widespread and so far we have seen no resistance.

BILL BARR: Do you sterilize the rooting medium?

DAVID MORGAN: No.

CHARLES GILLIAM: I was asked about the effect of Classic on nutsedge. Classic is good, but it is hard on ornamentals. Dual looks like it will be good.

BILL DAUGHERTY: We have been able to get good control with Classic with as low a rate as ¼ oz. per acre. We haven't seen much damage to ornamentals. However, it is extremely important to be specific and use an appropriate chemical for each problem.

HUGH STRAIN: We have been using Basogran, as does Tommy Loder.

MICHAEL DIRR: There has been a question on rooting Leyland cypress. We use 0.3 to 0.8% IBA in January and stick in a 2:1 perlite:peat mix. We syringe but don't mist the cuttings. They root in 10 to 12 weeks.

BILL BARR: Joe Powell's paper in a past Proceedings is good on this. We use 5000 ppm IBA and stick cuttings in the same mix we use for dwarf nandina.

SHIVU PATEL: We use a 1:10 Dip 'n-Gro solution. We include one to two inches of brown wood at the base of the cutting.